TC 9385-05

SITE INVESTIGATION
LIVINGSTON FREEWAY
LIVINGSTON, CA

FINAL REPORT

Contract No. 53S515
Task Order No. 10-316931-05

Prepared for

Caltrans
District 10
1976 E. Charter Way
Stockton, CA 95201

October, 1993

Prepared by

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October 5, 1993

Mr. Gary Sweeten
Contracts Manager
California Department of Transportation
District 10
1976 E. Charter Way
P.O. Box 2048
Stockton, CA 95201

Subject:Submittal of Final Site Investigation Report for Livingston Freeway, Contract No. 53S515, Task Order No. 10-316931-05, TC 9385-05.

Dear Mr. Sweeten:

I have enclosed eight copies of the text portion of the final Site Investigation Report for the Livingston Freeway Site Investigation. I have also enclosed eight sets of covers to finalize the reports for the investigation at Medina's Garage (Site 4), and the report for the geophysical investigations (Site 3).

I have also attached a list of the job titles of personnel who have worked on the project, and whose time cards were provided to you with the final invoice already sent to you.

If you have any questions, please do not hesitate to call me at (415) 974-1221.

Very truly yours,

Tom Whitehead
Project Manager

enclosure

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1.0 INVESTIGATIVE SUMMARY

1.0 INVESTIGATION SUMMARY

Tetra Tech performed a Site Investigation of the Livingston Freeway right of way in Livingston, Merced County, California. The investigation was directed toward gathering chemical and hydrogeologic evidence to identify the source(s) and parties responsible for soil and ground water contamination in the Livingston Plaza area. The volume of floating product beneath the site was estimated to be approximately 22,000 gals. Additional gasoline trapped in the soil, dissolved in ground water, or present in vapor phase in soils is estimated to be as much as 37,000 gals.

Tetra Tech evaluated hydrologic and soil and ground water analytical data from previous investigations at the site. Ground water contour maps were prepared from previous data to evaluate changes in ground water flow patterns at the site. Tetra Tech installed four new monitoring wells at strategic locations to further evaluate the gasoline floating product plume geometry and the hydrogeologic conditions near the plume. Tetra Tech also performed detailed chemical analysis of the gasoline product to test the theory of one of the potentially responsible parties (Chevron Oil Co.) that the gasoline was too young to have been spilled when Chevron operated tanks at 1344 Highway 99. Soil samples from eight borings, in addition to the monitoring well borings, were drilled and sampled to evaluate potential source areas in further detail. Three continuous cored borings were drilled and logged to identify stratigraphic features that might influence contaminant transport.

Three potential source areas were identified in previous investigations of the site, including the former Chevron Oil service station property (1344 Highway 99), the former Livingston Mini Mart service station property (1410 Highway 99), and the former Chavez Auto Repair property (1444 Highway 99). Ownership of the properties has changed several times over the period of interest at the site. Therefore, identification of responsible parties requires determining the age of the gasoline, determining the point of release, and explaining the sequence of events that account for the observed conditions.

Tetra Tech identified two separate product plumes, one originating at 1410 Highway 99 and one originating at 1444 Highway 99, based on chemical and hydrogeologic evidence. The product plume that

originated at 1410 Highway 99 contained an estimated 22,000 gals of floating gasoline product in April, 1993. One or more of three distinct sources identified at the 1410 Highway 99 property from soil sampling data, may have contributed to this plume. The plume that originated at 1444 Highway 99 was smaller, and contained an estimated 75 gals of floating gasoline product in April, 1993. All product samples were determined to be weathered gasoline, from which approximately 50 percent of the original benzene concentration has evaporated. This represents a larger percentage loss of benzene than was previously estimated by Chevron, suggesting that the age of the gasoline may be greater than was previously estimated by Chevron. However, an upper age limit for the floating product was not determined.

No evidence indicative of a release from tanks or associated piping was observed in soil samples collected at from 1344 Highway 99. Gasoline contamination observed near the depth of the water table was interpreted to have originated from migration of the floating product plume. Evidence for a more west-trending hydraulic gradient prior to 1989 may account for the observed distribution of the product plume.

2.0 INTRODUCTION

2.0 INTRODUCTION

Tetra Tech performed a Site Investigation in the proposed Livingston Freeway right of way for Caltrans District 10 pursuant to Task Order No. 10-316931-05 under Contract No. 53S515. The study area of the investigation is located south of Highway 99 in the City of Livingston, in Merced County as shown on Figure 1.

Highway 99 is a major north-south route, with one remaining stoplight, located in the City of Livingston. The proposed freeway construction project is intended to straighten the section of Highway 99 which passes through Livingston, moving the roadway south of its current route and eliminating the stoplight. The plans call for constructing the roadway about 20 ft below grade.

An initial environmental investigation of the site, in 1989, identified a gasoline product plume on the ground water table beneath the site. Subsequent investigations, the results of which are summarized below, have attempted to further define the extent of the gasoline contamination in soil and ground water in the central area of the site, herein called the Livingston Plaza area, and to identify other areas and sources of contamination within the proposed freeway right of way.

2.1 PURPOSE

The overall purpose of this Site Investigation is to further investigate and define potential sources of soil and ground water contamination in the right of way of the proposed Livingston Freeway Alignment, to investigate shallow soils on the property occupied by Medina's Auto Repair (Site 4), and to investigate three potential underground storage tank locations (including Site 3) using geophysical methods. The locations of these investigation areas, the approximate boundaries of the Livingston Freeway right of way, locations of borings and monitoring wells installed in previous investigations, and locations of previous and existing buildings and site features are shown on Figure 2.

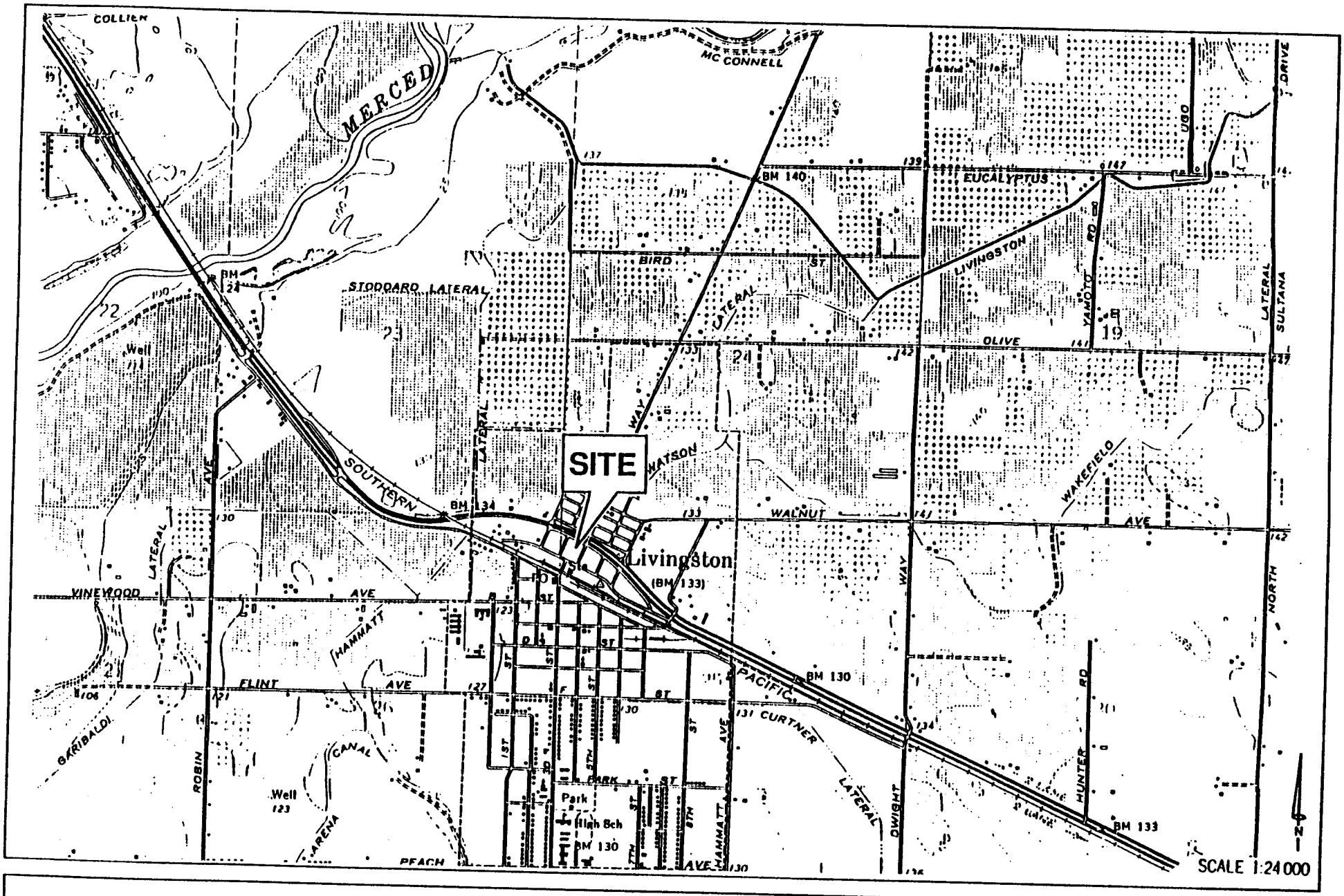
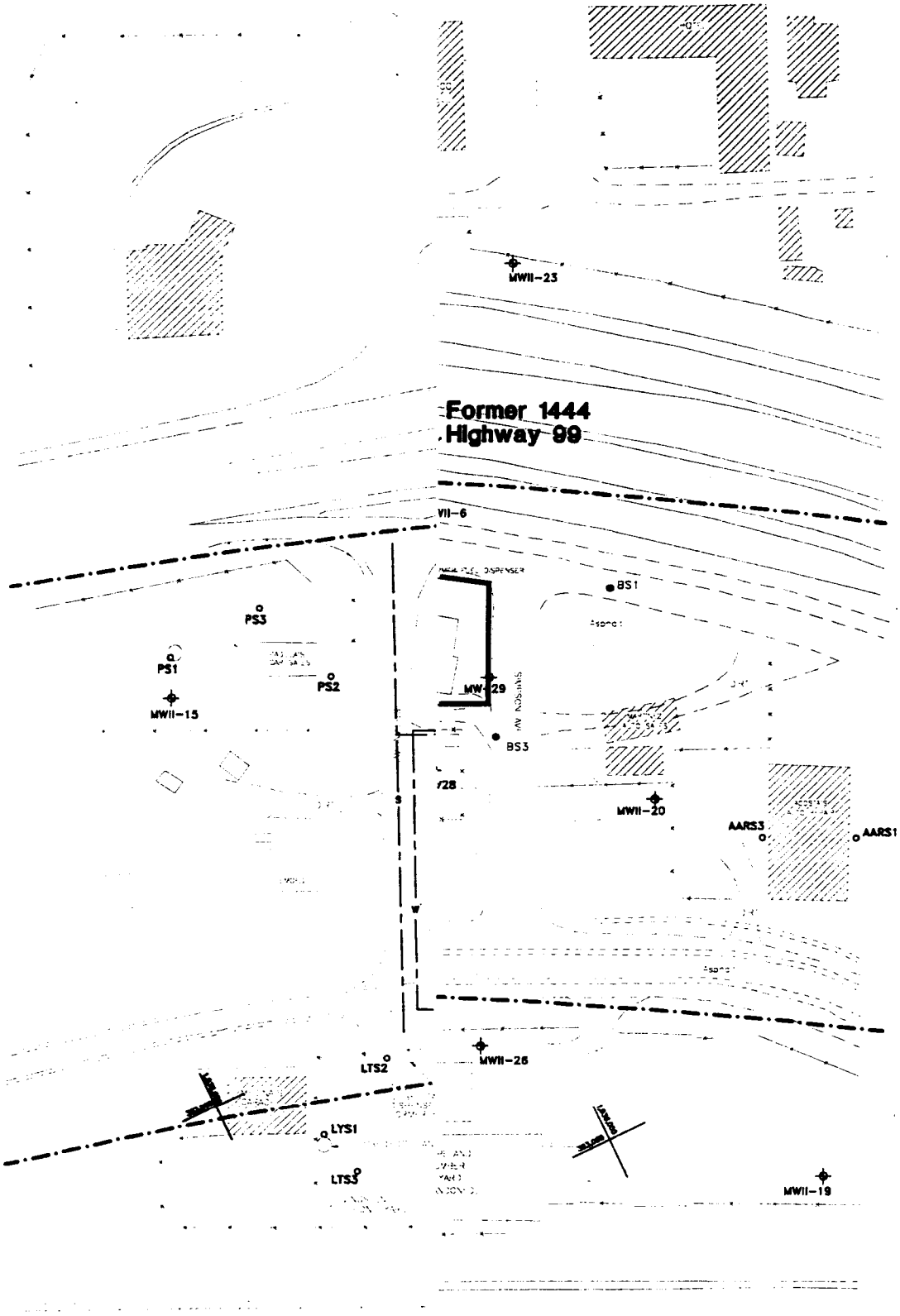


Figure 1 **Site Location**



EXPLANATION	
Borings from previous Previous investigations	-G-W-S- Underground G=Gas, W and S=
AARS1 Hand Auger Soil Boring	
MWII-20 Monitoring Well	Existing
US1 Soil Boring	Approximate Boundary Right of

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Site Plan
Site Investigation Report
Livingston, California

Figure 2

Separate reports have been prepared describing the results of each of these three investigations. This report describes the results of the investigation of the sources of the gasoline product in the Livingston Plaza area.

2.2 OBJECTIVES

The objectives of the Site Investigation of the gasoline plume in the Livingston Plaza area, as stated in the Work Plan (Tetra Tech 1993a), are:

- Obtain additional data, through soil sampling and installation and sampling of new and existing monitoring wells, pertaining to the origin(s) of petroleum contamination in soils and ground water in the region of a known floating product plume located in the central portion of the Livingston Freeway project area (the general area occupied by Sites 1 and 2 of the Task Order); and

- Perform forensic geochemical data evaluations and additional chemical studies, if appropriate, to help identify parties responsible for past petroleum hydrocarbon releases, particularly in the region affected by floating gasoline product.

2.3 SITE HISTORY

The following site history is summarized based on reports from previous investigations and from correspondence and other documentation provided by Caltrans District 10. For further details about the site, please consult the documents cited below, or excerpts contained in Appendix H.

2.3.1 Land Ownership

Historically, Highway 99 has been a major thoroughfare through the City of Livingston, supporting service stations, garages, and other vehicle-related businesses, many of which owned underground fuel storage tanks. Prior to the 1920's, Highway 99 was routed through the town of Livingston along Court Street (see Figure 2). Highway 99 was subsequently routed along what is now Frontage Road, and was then relocated to its present route, north of Frontage Road These changes in the routing of Highway 99 were accompanied by corresponding changes in the locations of roadside businesses, including service stations (G. Sweeten, personal communication).

The factual data related to land ownership in the following section is taken from documents prepared by staff of the Central Valley Regional Water Quality Control Board (CVRWQCB 1992).

From 1938 to 1972, the Standard Oil Company of California owned and operated a gasoline service station at the corner of Third Street (now renamed Cressey Street) and old Highway 99 (Frontage Road) at 1344 Highway 99. The station formerly occupied parcel no. 24-081-01, which is now the northeast corner of parcel no. 24-081-07. In 1974 the property was sold to Robert W. Riechel, who sold the property in 1980 to Richard J. Berger, the present owner. Chevron contends that the underground storage tanks were removed prior to the sale, and subsequent investigation by Caltrans indicates that the tanks have been removed. No documentation of the tank removal was available for review, however. Mr. Berger constructed the Plaza Shopping Center over the former underground tank pit. Figure 2 shows the location of the Plaza Shopping Center and the approximate boundaries of the former Chevron Station. The Shopping Center was demolished by Caltrans in 1992, and the property is currently a vacant, unpaved lot.

The corner opposite the former Chevron Service Station on the east side of Cressey Street, at 1410 Highway 99, was occupied by another service station. From 1967 to 1973, the property was leased by Leslie and Kathleen Jirsa, and the service station reportedly sold ARCO gasoline. From 1972 to 1981 the property was owned by Jimmie and Elizabeth Ingram, who operated the station from 1973 to 1975. The Ingrams' leased the property to Leonard and Shirley Blevins in 1975, who subsequently purchased

it in 1981. The Blevins' operated the station from 1975 to 1986. From 1986 to 1989 the station was operated by Paul Oil Company. From 1989 until 1990, when it was closed, the station was operated by Jeronimo and Marie Fuentes.

At some time, the tanks at 1410 Highway 99 were taken out of service and tanks on the adjacent property at 1444 Highway 99 were connected to the dispensers at 1410 Highway 99. The date when this connection occurred is not precisely known, although it is presumed to have occurred after 1981, when Shell Oil Company operated the station at 1444 Highway 99. It is likely that the tanks were removed when the pipeline connection was made (G. Sweeten, personal communication). Except for a 3,000-gal diesel tank, the locations of the former underground tanks at 1410 Highway 99 were not identified in the documents reviewed by Tetra Tech. The date of installation of the 3,000-gal diesel tank is not known. Only the 3,000-gal diesel tank was present at 1410 Highway 99 when it was removed and the buildings were demolished by Caltrans in 1992 (G. Sweeten, personal communication).

From 1938 to 1974, the property adjacent and to the east of 1410 Highway 99, at 1444 Highway 99, was owned by Mr. and Mrs W.R. Stinnett. The Stinnetts leased the property to Shell Oil Company, which operated a station during that period. In 1974, the property was purchased by the present owners, Leonard and Shirley Blevins, who operated the service station until 1986. The property is identified as Chavez Auto Repair on Figure 2. From 1986 to 1989, the tanks at 1444 Highway 99 were operated by Paul Oil Company. Fuels were dispensed at the station at 1410 Highway 99. Jeronimo and Marie Fuentes operated the tanks at 1444 Highway 99 from 1989 until the station closed in 1990. The tanks were removed and the buildings were demolished in 1992 under Caltrans supervision.

2.3.2 *Previous Investigations*

In March of 1989, an Initial Site Assessment was completed by Dynamac Corp for Caltrans, identifying 22 potential hazardous waste sites within the proposed freeway right of way. In May of 1989, CKY Inc., completed an initial Site Investigation (Phase I). A soil gas survey was performed, shallow hand augured borings (e.g. AARS-1) were sampled, and eleven 2-inch diameter PVC monitoring wells (MW1 through MW11) were installed. Soils and ground water samples were analyzed for total recoverable hydrocarbons (TRPH) by EPA Method 418.1, total petroleum hydrocarbons (TPH) by EPA Method 8015

(modified for diesel and gasoline), benzene, toluene, ethylbenzene, and total xylenes (BTEX) by EPA Method 8020, organophosphorus pesticides by EPA Method 8140, volatile organics by EPA Method 8240, and semivolatile organics by EPA Method 8270.

Soil gas results indicated the presence of volatile hydrocarbon contamination in soils in the vicinity of former underground tanks at 1410 and 1444 Highway 99, and at 1344 Highway 99. Monitoring wells MW-4, MW-6, MW-7, and MW-8 were installed to investigate groundwater in the vicinity of these sites (see Figure 2 for locations of wells and borings). Approximately 1.5 ft of free gasoline product was observed in MW-4, although the concentrations of gasoline in soils near the water table were not extreme (470 ppm at 35 ft, not detected at 40 ft). At MW-8, elevated levels of gasoline were detected in soil samples from 5 ft to 40 ft. Concentrations in soil samples ranged from 1900 ppm to 20,400 ppm. No gasoline product was observed in either MW-6, MW-7, or MW-8, however. (Copies of relevant material from the 1989 CKY investigation are presented in Appendix H1. of this report).

In 1990, CKY Inc. performed additional soil and ground water investigations (Phase II). The investigation focused on the Livingston Plaza Area, the Yagi Brothers Produce Site, and the Blueberry Hill Truckstop Site. Results from the Livingston Plaza Area are described below.

A pilot soil gas survey was performed to evaluate the feasibility of using soil gas as a tool for identifying areas with subsurface contamination. It was concluded that the pilot test failed to predict known contaminated locations and the soil gas survey technique was not further used. (One of the reasons for the failure of the pilot test may have been that the soil gas probes were not placed deep enough to penetrate the fine-grained, iron-cemented hard pan zone which extends to a depth of about 15 ft throughout the site).

A total of twenty-six 4-inch PVC monitoring wells (MWII-1 through MWII-26), and four 2-inch piezometers (BS-1, BS-2, BS-3, and BL-1) were installed during the Phase II investigation. (Note that the previously-installed 2-inch wells were labelled MW-1 through MW-11, without the "II" identifier). The piezometers were not developed, but water samples were collected from BL-1, BS-1 and BS-3 after installation. Three vapor extraction wells were also installed (VES-1, VES-2, and VES-3) with screens set between 20 to 40 ft below ground surface. Nine additional soil borings were drilled (B-12, B-13, BB-1 through BB-5, BL-2, BL-3, and BS-4 through BS-8).

Based on the assumption that the thickness of gasoline product observed in monitoring wells represents four times the thickness of product on the water table, CKY calculated that approximately 20,000 gallons of gasoline product were present, covering an area of about 68,000 sq ft. CKY identified 1444 Highway 99 as the most likely source of the product spill, although they also identified 1344 Highway 99 as a potential source.

CKY performed three rounds of ground water sampling (January, February, and March, 1990). Soil and ground water samples were analyzed for TPH by Method 8015, for BTEX by Method 602/8020, and for halogenated volatile organics by Method 601/8010. Ground water samples were analyzed for sulfides, sulfates, nitrates, specific conductance, and total dissolved solids. Soil samples were analyzed for organic lead by the LUFT Manual method. Organic lead was only detected in soil samples from between 33 and 41 ft in boring BS-5. Excerpts from the 1990 CKY report are presented in Appendix H2.

During the 1990 soil and ground water investigation by CKY the buildings, including Livingston Plaza, were still in place. 1344 Highway 99 was not accessible for drilling. Attempts to drill borings at accessible locations south of 1344 were unsuccessful due to encountering refusal at shallow depth. In September of 1992, Caltrans further investigated the subsurface in the area of the former Chevron station by excavating an approximately 30 ft square area at the corner of Cressey and Frontage Road to a depth of about 12 ft with a backhoe. This area was thought to be the location of the former Chevron tanks. The rubble was removed and the excavation was backfilled with clean sandy soil, which was not compacted. No written report was prepared for this work. However, Gary Sweeten of Caltrans reported (personal communication 1993) that there was no evidence of soil contamination in the excavated soil. A diagram of the former service station site showing the locations of tanks, dispensers and other features is included in Appendix H3. The diagram was provided to the CVRWQCB by Chevron.

During building demolition operations at an abandoned house (east of MWII-5 on Figure 2) a 13,000 gal underground diesel tank was encountered. The tank was removed by ETS Environmental Inc. in May of 1990 (ETS Environmental & Associates, Inc. 1990). Since soil contamination was detected beneath the tank, further investigation of the site was performed. The tank excavation was backfilled on April 2, 1992. Geo/Resources Consultants (1992) drilled two borings (BC-1 and BC-2) to a depth of 45 ft within the perimeter of the tank excavation, and installed three monitoring wells (MWII-27, MWII-28,

and MWII-29) around the former tank. MWII-28 was installed downgradient of the tank. Although some soil contamination was encountered, diesel was not detected in ground water, indicating that the fuel leak from the tank did not impact ground water. It was recommended that additional borings be drilled in the area of the tank and of MWII-28 to further define the lateral extent of soil contamination. Excerpts from the report are presented in Appendix H4.

On September 30, 1992, 5 underground storage tanks and related piping were removed from the former service stations at 1410 and 1444 Highway 99, by Kroeker Environmental of Fresno. Soil samples were subsequently collected by Krazan & Associates (1992). A 3,000 gal diesel tank was located at 1410 Highway 99. An 8,000 gal tank (which formerly contained leaded regular), a 5,000 gal tank (which formerly contained unleaded supreme), a 5,000 gal tank (which formerly contained unleaded regular), and a 120 gal waste oil tank, were located at 1444 Highway 99. The former contents of the tanks were identified in a diagram on a permit to perform a precision test, issued by the Merced county Health Department, and dated May 12, 1988. The tank closure report for the tanks indicates that the gasoline tanks were in good condition, with surface rusting. However, a hole was noted in one end of the diesel tank, and a "number of visible holes" were observed in the waste oil tank. In addition, soil discoloration was noted in the backfill and native soil around the gasoline tanks (Krazan & Associates 1992).

Soil sampling was performed after the tanks were removed at 15 locations adjacent to the tanks and along a pipeline extending from the gasoline tanks at 1444 Highway 99 to the fuel dispensers located at 1410 Highway 99. Diesel and gasoline were detected at 37,000 and 35,000 ppm, respectively, and organic lead was detected at 28 ppm, in one sample taken from a depth of 12 ft between the unleaded and leaded regular tanks at 1444 Highway 99. Gasoline and diesel were also detected at about 1000 ppm each in one sample taken from a depth of 3 ft from a point along the product lines from the gasoline tanks, about 40 ft east of the diesel tank. The latter sample point is located near MW-8. A sample taken from 5 ft beneath the former waste oil tank contained 1100 ppm oil and grease. No semivolatile organics were detected in the sample associated with the waste oil tank. Excerpts from the Krazan & Associates report are included in Appendix H5.

In 1992, TRC Environmental installed pressure monitoring wells (PMW-1, PMW-2, and PMW-3) on the former Livingston Mini Mart site around MWII-7, as part of a pilot vapor extraction system which would use MWII-7 as a vapor extraction well.

Most of the field work for the current investigation was performed between March 25, 1993 and May 20, 1993. Shortly thereafter, TRC Environmental installed cyclone fencing around the site, in preparation for full scale operation of a vapor extraction system to remediate gasoline in soils and ground water within the Livingston Freeway right of way.

2.3.3 Regulatory History

The chronological sequence of regulatory actions associated with the site is as follows:

- September 8, 1989 - Caltrans informed the Merced County Environmental Health Department (MCEHD) and the Central Valley Regional Water Quality Control Board (CVRWQCB) of contamination of soil and ground water in the proposed freeway right of way.

- January 9, 1990 - Merced County placed all sites found to have contamination from underground tanks on the State Board Underground Tank Pilot Program.

- June 13, 1990 - MCEHD directed the parties identified as dischargers to begin removal of free product and submit Problem Assessment Reports by August 6, 1990.

- October 31, 1991 - MCEHD requested that the CVRWQCB adopt Cleanup and Abatement Orders since the County had been unsuccessful in enforcing the cleanup of the site.

- February/March, 1992 - A CVRWQCB hearing was held in February, 1992, and continued in March, 1992, to consider issuing Cleanup and Abatement Orders requiring the completion of the investigation and remediation of contamination. The C & A's have not yet been issued.

2.4 PROJECT DESCRIPTION

Previous investigations have determined that the subsurface has been impacted by releases of petroleum hydrocarbons, including one or more releases that resulted in a plume estimated to contain 20,000 gals of floating gasoline product covering approximately 68,000 square feet (nearly 2 acres) of the water table. Four subsites were identified by Caltrans in the task order for the investigation (Sites 1, 2, 3, and 4). In this report, the site is defined as the region within the Livingston Freeway right of way that is impacted by petroleum hydrocarbon contamination associated with former leaking underground fuel tanks and associated piping which were located on properties between White Avenue and Simpson Avenue. Several monitoring wells outside the Livingston Plaza area site as defined above (such as upgradient well MWII-22 and downgradient well MWII-18, are also included in the ground water monitoring program for the site. The investigations of Sites 3 and 4 are addressed in separate reports.

The Livingston Freeway right of way in the Livingston Plaza area has been cleared of all structures and pavement, except the pavement on city streets. A major water line and a sewer line are located beneath a former alley which bisected the site. Three former service stations, which are the principal focus of the source identification objective of this investigation, and which operated between 1938 to 1989, were located north of the alley along Frontage Road. These include a former Chevron station at 1344 Highway 99; the former Livingston Mini Mart, at 1410 Highway 99; and the former Chavez Auto Repair, at 1444 Highway 99.

2.4.1 *Land Use*

The Site Investigation area lies within the City of Livingston in a primarily commercially developed area between Highway 99 and the Southern Pacific Railroad line, and includes the right of way for the planned realignment of Highway 99. Central Livingston is located south of the Southern Pacific Railroad tracks, and includes City offices and residential neighborhoods. Highway 99 divides the northern portion of Livingston from the southern portion.

2.4.2 *Regional Geologic Setting*

The regional geologic setting has been described in some detail in the Initial Site Assessment Final Report (Dynamac Corporation 1989), which has been drawn on for the following summary.

Livingston is located within the east-central San Joaquin Valley, a large structural basin filled with alluvium derived from erosion of the Sierra Nevada to the east, and from the Coast Ranges to the west. The valley is underlain by consolidated Cretaceous to Tertiary sandstones and shales, and late Tertiary to Recent unconsolidated sediments. The stratigraphic units in the Livingston area, from youngest to oldest, are as follows:

- At the land surface, in some locations, is a thin, wind-deposited dune sand derived from underlying units.

- The Modesto Formation, consisting of Quaternary fan and terrace deposits ranging from 10 to 30 ft thick in the Livingston area, is represented by a sequence of laminated silty sands, coarsening upward. The sediments are described as poorly sorted, clay to gravel-sized particles derived from granitic and metamorphic rocks.

- The Riverbank Formation is very similar in composition and grain size distribution to the Modesto Formation and ranges from 15 to 30 ft thick in the site area. An extensive, strongly-developed silica-cemented hardpan is developed in the upper sand beds of the Riverbank Formation. The CKY final Site Investigation Report (1990) refers to this hardpan as a silica-rich *iron-cemented* unit. Boring logs from the site suggest that the hardpan is stained with iron oxide.

- The Turlock Lake Formation is an older alluvial fan unit which is reported to be over 100 ft thick in the project area. The top of the formation contains a 10 to 30 ft thick coarse sand, described as an important aquifer unit. The sand unit is underlain by a light-gray, thinly laminated silt and very fine sand unit up to 40 ft thick. This is underlain by another sequence of coarse sand underlain by fine

material. The Corcoran Clay, now more specifically referred to as the "E-Clay", a regionally extensive, lacustrine, diatomaceous clay aquitard unit, lies within the Turlock Formation.

Together, the Modesto, Riverbank, and Turlock Lake formations are referred to as the "older alluvium", as distinguished from recent alluvium which occurs adjacent to incised streams such as the Merced River.

Below the Turlock Formation is the Merten Formation, a consolidated Tertiary fluvial deposit containing conglomerate, sandstone, and claystone. The formation is dark due to an abundance of andesitic materials. The Merten is reported to coincide with the base of the freshwater-producing zone.

CKY (1990) reported that the subsurface soils encountered at the site were generally poorly graded fine to medium grained sands, and poorly graded silty sands to a depth of about 40 ft. From 40 ft (the depth of the water table at the time) to 58 ft, the sands are predominantly fine to medium grained. A silty loam/clay, about 5 ft thick, was frequently observed in the 50 to 58 ft depth range. They also noted that thin, cemented siltstone beds were encountered at depths between 10 and 16 ft.

2.4.3 Regional Hydrogeology

Historical changes in direction of the hydraulic gradient may help to explain the current distribution of dissolved and free product phases of gasoline at the site. The distribution of gasoline is discussed in greater detail in later sections, but the hydraulic conditions that may have impacted that distribution are discussed here.

Four ground water zones are reported in the Livingston area according to Dynamac (1989). The first occurrence of ground water is a perched aquifer resting on the hardpan that marks the top of the Riverside Formation. Perched ground water was not observed in the previous site investigations conducted since 1989.

The shallow, unconfined aquifer is reported to extend to the top of the E-Clay in the Turlock Formation, at a depth of some 100 to 200 ft. The water table has reportedly been decreasing in recent years, partly as a result of increased ground water withdrawals, and partly as a result of decreased recharge due to drought. Most of the wells in the Livingston area are completed within the unconfined aquifer. Historic ground water measurements of local wells are presented in Appendix H6.

A confined aquifer occurs below the lacustrine E-Clay in the Turlock Formation, at depths of about 250 to 350 ft. This is reportedly a very high-yielding aquifer. A second confined unit occurs in the consolidated Merten Formation, at a depth of about 600 to 700 ft.

The hydraulic gradient in the unconfined aquifer at the site has been reported to be toward the south-southwest based on ground water elevations in on site wells measured in previous investigations (CKY 1990). Historically, however, the gradient may have been more toward the north-northwest, in the direction of the Merced River. This is shown on maps of the unconfined water table produced by the Department of Water Resources between 1985 and 1988. While these maps are at a small scale, and may not be accurate at the scale of the site, they indicate that the Merced River was a gaining stream (water flowed from the aquifer toward the river) in the vicinity of Livingston. (One of these maps was reproduced in the site assessment report (Dynamic, 1989).

Data compiled by Caltrans (1991) suggest that prior to 1960 the unconfined water table was probably at a depth of less than 20 ft beneath the site (elevation greater than about 112 ft above mean sea level). The data indicate that water levels declined during the 1960s, and stabilized between 1969 to 1987, with water table elevations fluctuating between 95 to 100 ft above mean sea level (msl) in the site vicinity throughout the 1969 to 1987 period. Since the base level of the shallow aquifer is controlled by the (relatively constant) elevation of the Merced River, it makes sense that at times when the water level in the aquifer was higher than that in the river, a component of flow would have been in the direction of the river. Likewise, at times when water levels in the aquifer were below the level of the river, a component of flow would have been away from the river. Therefore, as the elevation of the water table has decreased, the direction of the hydraulic component contributed by the river may have reversed.

The decreases in water level in the unconfined aquifer are probably attributable to decreases in recharge, due to drought and reduced flows in streams, and to increases in the amount of ground water

withdrawals from irrigation and domestic wells. The direction of flow at the site may be influenced by local pumping from irrigation and domestic wells. Also, although our data are limited to the horizontal component of flow, there may be a vertical component of flow at the site as well.

Among the potential local influences on hydrology at the site are private wells and municipal drinking water production wells owned by the City of Livingston. A map of well locations in the site vicinity, and copies of boring logs for four municipal wells are included in Appendix H7. One of the wells (W-9, or Foster Farms #2) is located just west of Davis Street, about 1000 ft northwest of the former Livingston Plaza. This well is screened from 65 ft to 265 ft, and is reportedly operated seasonally, during the summer. A second well (W-4) is located near the police station at 4th Street and C Street (about 700 ft south of the former Livingston Plaza). This well was reportedly taken out of service two years ago due to the presence of contamination with the pesticide DBCP (personal communication with Gary Petty). The possible influence of offsite production wells on the hydraulic gradient at the site has not been studied.

Between August 1989, the first round of monitoring well sampling at the project site, and July 1992, the most recent sampling event prior to this investigation, water levels have declined approximately 8 ft (CKY 1989; Krazan & Associates 1992). In April of 1990 the water table beneath the Site Investigation area was at an elevation of about 90 ft msl (approximately 40 ft below the ground surface) according to CKY (1990). In July of 1992 water levels had dropped by about 7 ft in the area, to about 83 ft msl (Krazan & Associates 1992). Interpretation of the historical water levels and the direction of the hydraulic gradient are presented in Section 4.0.

2.4.4 Previous Gasoline Product Chemistry Studies

Product samples were collected in March of 1992 by Krazan & Associates for Chevron. The samples were collected for a chemical fingerprinting analysis. Ground water levels and product thickness were also measured by Krazen & Associates at the time the samples were collected. Product samples collected from MW-4, MWII-5, MWII-24, and MWII-22 were analyzed by Chevron Research on April 17, 1992. Chevron claimed that all of the product from these wells came from a single source, based on their interpretation of hydrocarbon composition and on tetraalkyllead isomer distribution and concentration

(Harvey 1992). Based on the benzene concentration (1.3 to 1.6 percent) and tetraalkyllead concentration (0.06 to 0.10 grams/gallon), Chevron concluded that the gasoline product was a leaded regular gasoline manufactured between 1985 and 1989. Chevron also noted that as much as 1 to 2 ppm of inorganic lead in ground water could be expected to be found at sites of old leaded gasoline spills. They also pointed to lack of dissolved lead in the ground water at the site in support of a relatively young age for the gasoline. However, ground water samples had not been previously analyzed for dissolved lead, so this conclusion was not founded.

Subsequently, Chevron analyzed eight product samples, including one sample from MWII-5, one sample from MW-6, three samples from MWII-22, and three samples from MWII-24, to "Identify the product and determine whether they are similar, estimate the age of the hydrocarbons present, and compare with previous samples from this site" (Chevron Research 1992). Chevron concluded that the gasoline in wells MWII-5, MWII-22, and MWII-24 came from the same source, based on the similar lead and benzene concentrations, and was manufactured between 1985 and 1990. They concluded that the gasoline in MW-6 came from a different source, based on its higher lead content, and was probably manufactured between 1978 and 1984.

3.0 INVESTIGATIVE METHODS

3.0 INVESTIGATIVE METHODS

Tetra Tech performed field work between March 25 and April 20, 1993. Activities included an initial round of water level measurements of 27 wells on March 25, drilling and sampling of borings and installation of monitoring wells from March 29 to April 6, monitoring well development on April 6, a second round of water level measurements and product sampling on April 8, and ground water sampling from April 8 to April 13. This section describes the approach and methods used.

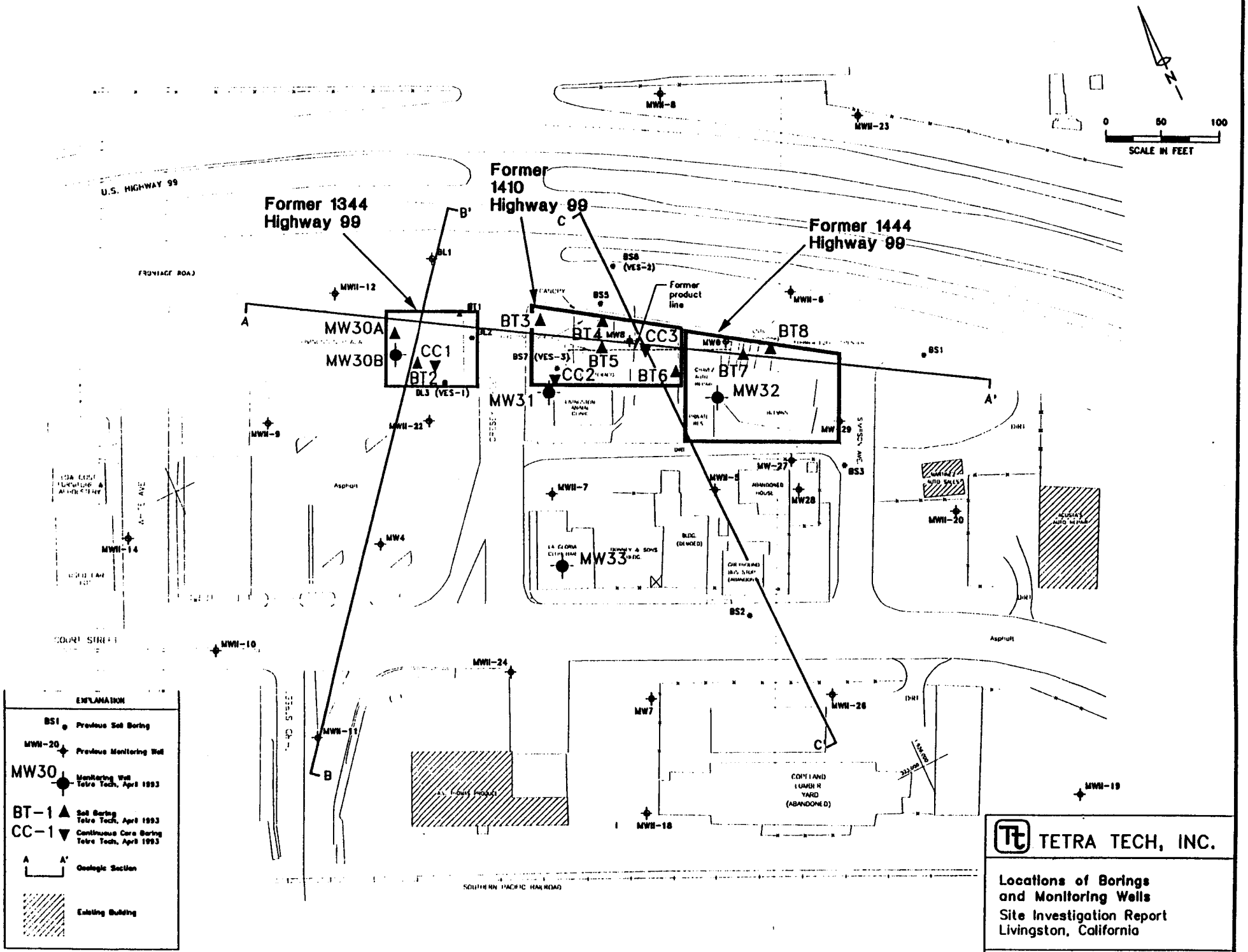
Prior to starting work, Underground Service Alert (USA) was contacted to identify and mark underground utilities in the Site Investigation area (#84960). No underground utilities were located in the immediate vicinity of any of the borings.

3.1 DRILLING AND SOIL SAMPLING

Eleven soil borings (BT-1 through BT-8, and CC-1 through CC-3) and four monitoring wells (MW-30 through MW-33) were drilled and sampled. Borings CC-1 through CC-3 were continuously cored. Borings BT1- through BT-8 were sampled at a minimum at 5 ft intervals, and at specific depths of interest, based on evaluation of the continuous cores. The locations of the borings and wells are plotted on Figure 3.

3.1.1 Rationales for Boring Placement

Borings CC-1, BT-1, BT-2 and MW-30 were located on the former Chevron Station site at 1344 Highway 99. According to the December 1961 drawing of the site provided by Chevron (Appendix H3), at least 5 underground tanks may have once been located in a 20 ft by 40 ft strip along the west side of the Chevron site. The northeastern corner of the site contained the fuel dispensers.



TETRA TECH, INC.

Locations of Borings and Monitoring Wells
Site Investigation Report
Livingston, California

Figure 3

During previous drilling and sampling investigations by CKY (1989, 1990), the former Chevron site at 1344 Highway 99 was not accessible because one of the Livingston Plaza shopping center buildings covered this site. After the buildings were demolished in 1992, Caltrans excavated an a pit approximately 20 by 20 ft to a depth of about 12 ft in the area of the former tanks to identify evidence of contamination associated with the tanks. During excavation of the pit, Caltrans encountered concrete rubble and removed it, but no tanks were encountered. No visual or olfactory evidence of soil contamination was observed (G. Sweeten, personal communication). The excavation was backfilled with clean sandy fill, which was visibly lighter in color than the native material.

In order to evaluate the undisturbed stratigraphy near the location of the former tanks, continuous core boring CC-1 was placed outside the southeast corner of the excavation pit. The continuous cores were intended to identify stratigraphic features that might influence contaminant migration, and to identify horizons of interest for sampling in the subsequent BT-series borings. No analytical samples were collected from the continuous core borings. BT-1 was placed in the northeast corner of the former Chevron station site, in the general area where the fuel dispensers were thought to have been located. BT-2 was placed in the backfilled excavation near the southern portion of the area which is thought to have contained the former underground fuel tanks. MW-30 was placed near the northern end of the former underground tank area. The rig's downhole hammer became disconnected in the hole while preparing to sample from a depth of 50 ft in MW-30. A portion of the hammer could not be retrieved and was abandoned in the hole, and the hole was grouted to the surface. The boring was labelled MW-30A, and a second monitoring well boring, labelled MW-30B, was drilled about 12 ft southwest of MW-30A, still within the former tank pit area. MW-30B was not sampled, and was completed as a monitoring well.

Borings BT-3 through BT-6 were located on the former Livingston Mini Mart property (1410 Highway 99). BT-3 was placed in the far northwest corner of the property, near the corner of Cressey Street and Frontage Road, an area that had not been previously investigated. Previous documents have not indicated where the former underground fuel tanks were located at this property. BT-4 was placed near the presumed location of one of the former fuel dispenser islands. Previous boring BS-5, which was located about 10 ft north of the former dispenser, contained 2,100 ppm of gasoline at a depth of 35 ft, an indication of possible proximity to a leak. BT-5 was placed in the presumed location of the other fuel dispenser island, at a point near which Krazan & Associates (1992) collected Sample No. 14 on product

line F at a depth of 3 ft. Sample No. 14 contained TPHd and TPHg above 1000 ppm. BT-6 was placed in the southeast corner of the property, which has not been previously investigated. Continuous core boring CC-3 was placed about midway between MW-8 and BT-6, to evaluate the undisturbed stratigraphy near MW-8, an area previously identified as a likely source of ground water contamination.

Monitoring well MW-31 and continuous core boring CC-2 were placed adjacent to the former Livingston Animal Clinic. MW-31 was placed about 30 ft north of the underground water and sewer lines beneath the former alley, and about 15 ft east of Cressey Street. CC-2 was located about 10 ft east of MW-31. The purpose of MW-31 was to further define water levels and product occurrence in the region of the apparently anomalously high water levels near MWII-7.

Borings BT-7, BT-8 and monitoring well MW-32 were located on the former Chavez Auto Repair property, at 1444 Highway 99. BT-7 was placed at a location between former unleaded regular and unleaded supreme tanks, where previous sampling by Krazan & Associates at a depth of 12 ft, found TPHd and TPHg above 35,000 ppm. The location was precisely located by triangulation from survey marks previously placed in the pavement of Frontage Road. The survey markers were installed by Caltrans to locate the centers of the former tanks when they were excavated in 1992. BT-8 was placed near the former fuel dispenser island, and was located precisely, from survey markers in the pavement of Frontage Road. MW-32 was placed about 50 ft southwest of MW-6 to further define the extent of the product plume in the generally downgradient direction from MW-6.

Monitoring well MW-33 was placed as near the corner of Court Street and Cressey Street, south of MWII-7, as possible while maintaining a safe distance from overhead lines at this location. The purpose of the monitoring well was to further define the extent of the gasoline product plume, and to help interpret the hydraulic gradient in this area.

3.1.2 Drilling and Drive Sampling

Drilling was performed by West Hazmat Drilling Corp., of Hayward, California, under the supervision of a Tetra Tech geologist. Borings were drilled with a hollow-stem auger drill rig using 8-in outer-diameter (O.D.) augers. Monitoring wells were drilled with a 10.25-inch O.D. hollow stem auger. Samples were collected with 18- or 24-inch long and 2-inch diameter split spoon samplers, driven at 5-ft intervals, and at additional intervals selected by the field geologist in consultation with Caltrans.

Samples were collected in 2-inch diameter by 3-inch long stainless steel sleeves. Four 3-inch sleeves were placed at the shoe end of the split spoon, and the remaining space in the barrel was taken up by either one or two 6-inch sleeves. The four 3-inch sleeves enabled split samples to be collected within a relatively short sample interval.

Split samples were provided to representatives of Chevron, the Shell Oil Co, and to the Central Valley Regional Water Quality Control Board (CVRWQCB). All samples, including the split samples were prepared by the Tetra Tech geologist and his assistant.

The sampling procedure was as follows. The split spoon sampler was recovered and opened by the driller, and handed over to the field geologist, who recorded the depth of the sample interval, the time, and the standard penetration blow counts in the boring log. The field geologist then examined the sample and recorded the sample recovery. The geologist carefully separated the liners and screened the sample for volatile hydrocarbons with the Flame Ionization Detector (FID), recording any observations. The 3-inch sample liners were labelled from A at the shoe end of the sampler to D at the top. In general, the second liner from the bottom (B) was retained by Tetra Tech, and the "C" liner was provided either to the representative of Chevron or the Shell Oil Co. In some locations and depth intervals, a "D" replicate sample was retained by Tetra Tech for geoforensic analysis. The bottom (A) liner was provided to the Water Board.

After screening with the FID, samples were prepared by placing a sheet of Teflon film over the ends of the sample, covering with snug-fitting plastic caps, and then sealing the caps with a non-adhesive silicon rubber tape. Sample numbers were written on the liner caps. Samples were placed inside ziplock plastic bags, and the samples were placed in a cooler, with ice, until distributed. Samples retained by

Tetra Tech were shipped under chain of custody to Diversified Analytical Laboratories, a California State certified Laboratory, in Inglewood, California.

Selected soil samples, which were suspected of containing residual gasoline product, were shipped to Curtis & Tompkins, Ltd, of Berkeley, California, for extended interpretive analysis of fuel composition. Samples for this extended analysis were selected from intervals where very strong odor, and high FID readings(greater than 10,000 ppm), indicated that the sample may have contained residual product. For these analyses, the samples from the top, or "D" liner were selected. An attempt was made to select these samples from representative locations throughout the study area, wherever high gasoline vapor concentrations were observed. One sample was collected from near the top of the soil column where high FID readings were first encountered, and from the depth of the capillary fringe (about 45 ft).

After preparing the analytical samples, the field geologist recorded the lithological description of the sample according to the Unified Soil Classification System (USCS), using the remaining recovered material, and noting any lithologic changes occurring in the interval retained for laboratory analysis.

Soil cuttings from the borings were placed in labelled 55 gallon DOT drums and stored onsite in a temporary fenced area near MWII-7 adjacent to Cressey Street. All auger flights and other downhole equipment were decontaminated prior to commencement of work and between borings using a steam cleaner. Decontamination water was contained in labelled drums and stored onsite pending sample analysis and final disposition. Soil sampling equipment was cleaned before and between each sampling event by scrubbing with a brush and laboratory-grade detergent, then rinsing in potable water, with a final rinse in distilled water, followed by air drying. The distilled water rinse was applied with a sprayer.

3.1.3 Continuous Coring and Continuous Drive Sampling

Continuous coring was attempted at three locations named CC-1, CC-2, and CC-3. Initially, a 5-ft long, 2-in diameter core barrel was used to collect the cores. This method had limited success due to poor recovery of sandy materials. The first attempt at CC-1, on the former Chevron site, got virtually no recovery to a depth of 15 ft. This hole was named CC-1A, and abandoned by backfilling with cuttings.

A second attempt was made at a location about 2-ft from the first with somewhat better results. In general, about 30 to 40 percent recovery was obtained with this method. It was decided by the field geologist to obtain the continuous core from CC-3 by continuous 24-inch split spoon drives. This method resulted in greater than 95 percent recovery.

Cores were placed in pre-fabricated waxed cardboard core boxes, designed to hold up to five 2-ft intervals. The core boxes were labeled with the boring number, the depth interval, and the orientation of the core. The field geologist logged some of the core in the field, and continued the logs later. The FID readings were made using a custom-made probe attachment fashioned from a plastic liner cap. The cap was slipped over the tip of the probe, with the open end of the cap pressed against the core. This enabled vapor from the core to accumulate in the air space trapped under the cap, which was sampled by the probe. Peak FID readings on each 2 ft interval were recorded in the boring log at the time the core was collected. Photographs of most of the core intervals were made in the field, and additional photographs were made later. The core logs are presented in Appendix A-2, and the photographs are presented in Appendix F.

3.1.4 Laboratory Analytical Methods for Soil Samples

All soil samples shipped to Diversified Analytical Laboratories were analyzed by the following suite of methods:

- EPA Method 8015/3550, modified for Total Extractable Hydrocarbons as diesel;
- EPA Method 8015/5030, modified to determine TPH as gasoline; and,
- EPA Method 8020, to determine Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX).

In addition, selected samples suspected of containing residual product were shipped to Curtis and Tompkins Laboratory, Ltd, of Berkeley, California, for analysis by EPA Method 8240 (GC/MS), to identify individual constituents of the fuel for potential comparison with the floating product samples and

comparison with previous fuel fingerprinting results reported by Chevron for samples from wells on the site.

Prior to analyzing the soil samples by Method 8240, the laboratory screened the samples using the California DOHS LUFT method to quantify Total Volatile Hydrocarbons as gasoline, as a cost-effective means of identifying whether gasoline residual product was indeed likely to be present.

3.2 MONITORING WELL INSTALLATION

3.2.1 Monitoring Well Construction

The locations and rationales for the monitoring wells have been described in section 3.1.1. All of the monitoring wells were completed at a depth of 60 ft BGS, with 25-ft screens. The monitoring well depth and screen interval were designed for several eventualities. The completion depth of 60 ft allows for up to 10 ft of additional water table lowering, and the 25 ft screens provide 15 ft of screen above the current water table in case water levels rise. Alternatively, the wells may be used in the vapor extraction system network as observation or extraction wells.

During well construction, a temporary wooden plug, which could be knocked out from above was placed in the bottom of the auger, while about 15 gals of distilled water were added to the auger to prevent loose formation sand from flowing into the augers. When the auger was retracted to set the well, the plug was pushed out. The wells were constructed with 4-inch diameter schedule 40 PVC casing and factory-slotted 0.01-inch screen, with 16 slots per inch. A filter pack of No. 2/12 sand was placed to a depth of 2 ft above the top of the screen. (The screen slot size and filter pack grain size selected for this project was slightly smaller than used in previous well installations, and was selected in order to screen out more of the fine fraction of the formation in the screened interval, based on particle size analysis for several sub-water table samples reported by CKY (1990). The choice of a smaller filter pack was motivated by reported turbidity in some of the existing wells). Bentonite pellets or bentonite chips were placed 3 ft above the sand pack, and hydrated for a minimum of one-half hour before grouting.

Cement-bentonite grout was tremmied into the annular space around the blank casing to make the sanitary seal. Traffic-proof, flush-mounted, water-proof well covers were installed at the ground surface to complete the well. Locking well plugs were installed. The identification number of the well was marked permanently on the cement seal. A permanent notch was cut on the outside edge of the top of the casing, to be used as a measurement datum.

3.2.2 Well Development

The wells were developed by West Hazmat after a minimum of 48 hours had passed to allow the grout in the annular seal to cure. Development was performed by gentle surging with a vented surge block, followed by pumping and bailing to remove sediment. Development logs are presented in Appendix A-4. Development water was contained in labelled drums, and staged in the temporary fenced drum storage area pending analytical results of ground water sampling from the wells. Water from wells which contained low levels of TPH and benzene were subsequently discharged to the sanitary sewer with permission from the City of Livingston Department of Public Works.

3.2.3 Well Survey

Wagner Engineering and Survey, Inc., of Van Nuys, California surveyed the newly-constructed monitoring wells and resurveyed monitoring wells MWII-27, MWII-28, MWII-29, MWII-5, and MWII-10, on April 8, 1993. The resurveyed wells were performed at Caltrans' request to check the accuracy of previous measurements, and because some of the locations were thought to be in error. For example, it was observed during water level measurement on March 25 that the vault for MWII-10 was loose, making it impossible to accurately read the depth to water from the vault cover datum previously used. The elevations of the three wells previously installed by Geo/Resources (MWII-27 through MWII-29) were suspected to be inaccurate, since the hydraulic gradient calculated from the reported elevations was not consistent with the gradient calculated from surrounding wells. The newly surveyed elevations were reported with an accuracy of 0.01 ft, and horizontal coordinates were reported to four decimal places. Measurements were made to the top of casing datum on both the new and resurveyed wells. The well

survey data and well construction information for the new wells, resurveyed wells, and the previously surveyed wells are presented in Table 1.

3.3 GROUND WATER SAMPLING

An initial round of water level measurements of 25 existing monitoring wells in the Livingston Plaza area was performed by Tetra Tech on March 25, 1993, to determine the depth to ground water, to evaluate the distribution of floating product, and to determine the direction of the hydraulic gradient, for planning the locations and construction of new monitoring wells. A second round of water level measurements of existing and new wells was performed on April 8, 1993, prior to sampling the wells, from April 10 to April 13.

3.3.1 Water Level Measurement

Tetra Tech measured water levels with an electronic water level meter with an interface probe, calibrated to read to the nearest 0.01 ft. The probe is used to measure the depth to both hydrocarbon product and to water. The probe is capable of detecting very thin layers of product, and was successful in reproducibly measuring product thickness of only 0.015 ft in MW-6.

Previously, most of the wells included in this round of water level measurements, with the exception of MWII-27, -28, and -29, had been surveyed to a point on the top of the vault covers. MWII-27, -28, and -29 were previously surveyed to a notch cut on the top of the well casing (TOC). Measurement to the top of casing is more accurate and easier to accomplish. Tetra Tech measured the depth to product and depth to water in each well to both the top of the rim of the vault and to the top of the casings, so that if the wells are resurveyed the elevations from the top of casing can be calculated. The measurement to the top of the vault rim was made from the bottom edge of a straight edge placed across the rim of the vault. This is the method reportedly used in the past to measure water levels. On wells where there was not already a reference notch on the top of the casing, Tetra Tech cut a small notch to be used as a reference point, and measured water levels from the notch.

TABLE 1 MONITORING WELL DATA

WELL ID	COORDINATES		WELL ELEVATION (1)	COMPLETION DEPTH	DEPTH TO BOTTOM OF SCREEN	ELEVATION BOTTOM OF SCREEN	DEPTH TO TOP OF SCREEN	SECREEN LENGTH
	NORTHING	EASTING						
MW-1	322,395.064	1,937,914.595	134.53	51.25	51.00	83.53	31	20
MW-2	322,330.686	1,937,933.914	134.56	52.87	53.00	81.56	33	20
MW-3	322,414.645	1,937,947.963	134.73	52.90	53.00	81.73	33	20
MW-4	323,378.064	1,935,644.096	130.17	52.03	52.00	78.17	32	20
MW-5	323,014.697	1,936,339.550	133.11	52.02	52.00	81.11	32	20
MW-6	323,413.673	1,935,998.006	132.68	51.55	51.50	81.18	31.5	20
MW-7	323,155.546	1,935,806.273	130.66	49.61	49.50	81.16	21.5	28
MW-8	323,450.355	1,935,919.755	132.09	50.69	49.50	82.59	30.5	19
MW-9	326,126.803	1,930,483.300	129.04	49.27	49.50	79.54	29.5	20
MW-10	326,051.026	1,930,542.359	130.07	49.18	49.00	81.07	29	20
MW-11	326,151.642	1,930,537.795	128.80	49.17	49.00	79.8	29	20
MWII-1	322,948.75	1,936,445.76	132.83	54.0	50.0	82.83	30	16
MWII-2	323,031.44	1,936,458.92	132.90	55.0	54.0	78.9	34	19
MWII-3	322,946.16	1,936,290.07	133.04	55.0	55.0	78.04	35	20
MWII-4	322,377.08	1,937,817.58	135.60	55.0	55.0	80.6	35	20
MWII-5 (2)	323,297.37	1,935,934.73	132.16	55.0	55.0	77.16	35	30
MWII-5 (2,4)	323,299.4655	1,935,934.6200	131.63					
MWII-6	323,427.38	1,936,065.12	132.56	55.0	55.0	77.56	25	20
MWII-7	323,354.77	1,935,802.39	130.55	55.0	55.0	75.55	35	25
MWII-8	323,634.84	1,936,033.85	131.05	54.0	50.0	81.05	30	14
MWII-9	323,521.86	1,935,597.34	130.62	56.0	56.0	74.62	36	22.5
MWII-10 (2)	323,359.18	1,935,474.94	129.59	53.5	53.5	76.09	33.5	28.5
MWII-10 (2,4)	323,359.3709	1,935,474.7407	129.13					
MWII-11	323,251.88	1,935,525.82	129.99	55.0	55.0	74.99	25	19
MWII-12	323,597.51	1,935,700.15	130.46	56.0	56.0	74.46	36	33
MWII-13	323,469.97	1,935,184.71	128.78	53.0	53.0	75.78	23	23
MWII-14	323,479.80	1,935,444.49	129.30	55.0	55.0	74.3	30	20
MWII-15	323,755.52	1,935,083.43	129.36	55.0	55.0	74.36	35	20
MWII-16	323,786.60	1,934,725.93	129.42	55.0	55.0	74.42	35	18
MWII-17 (2)	323,870.59	1,934,427.70	129.86	57.0	57.0	72.86	37	21.5
MWII-18	323,065.92	1,935,762.13	131.36	55.5	55.5	75.86	35.5	20
MWII-19	322,919.25	1,936,113.11	132.36	55.5	55.5	76.86	35.5	20.5
MWII-20	323,191.04	1,936,119.99	133.30	55.0	55.0	78.3	35	20
MWII-21	326,283.18	1,930,363.70	126.92	55.0	55.0	71.92	35	20
MWII-22	323,460.16	1,935,727.65	131.02	51.5	51.5	79.52	21.5	30
MWII-23	323,540.96	1,936,175.82	132.08	50.0	50.0	82.08	30	20
MWII-24	323,228.77	1,935,706.07	130.32	55.0	55.0	75.32	25	30
MWII-25	324,024.65	1,934,123.08	131.32	52.5	52.5	78.82	27.5	25
MWII-26	323,089.48	1,935,954.58	130.36	50.0	50.0	80.36	30	20

TABLE 1 (Continued), MONITORING WELL DATA

WELL ID	COORDINATES		WELL ELEVATION (1)	COMPLETION DEPTH	DEPTH TO BOTTOM OF SCREEN	ELEVATION BOTTOM OF SCREEN	DEPTH TO TOP OF SCREEN	SCREEN LENGTH
	NORTHING	EASTING						
MWII-27 (2,3)			131.71	58.0	58.0	73.71	28	30
MWII-27 (2,4)	323,292.5799	1,936,006.9783	131.60					
MWII-28 (2,3)			132.52	58.0	58.0	74.52	28	30
MWII-28 (2,4)	323,266.6143	1,935,998.1860	131.41					
MWII-29 (2,3)			132.14	60.0	60.0	72.14	40	20
MWII-29 (2,4)	323,309.6103	1,936,059.8299	132.03					
BS-1	323,327.28	1,936,148.16	N/A	46.0	46.0		26	20
BS-2	323,184.32	1,935,917.06	N/A	55.0	55.0		30	25
BS-3	323,271.39	1,936,042.95	N/A	46.0	46.0		21	25
BL-1	323,588.60	1,935,793.70	N/A	46.0	46.0		26	20
MWII-30 (2,4)	323,525.5440	1,935,729.3856	130.01	60.0	59.0	71.01	34.5	25
MWII-31 (2,4)	323,434.7093	1,935,833.0147	130.61	60.0	59.0	71.61	34.5	25
MWII-32 (2,4)	323,361.4231	1,935,976.0648	131.35	60.0	59.0	72.35	34.5	25
MWII-33 (2,4)	323,290.7801	1,935,783.8888	129.41	60.0	59.0	70.41	34.5	25

NOTES: (1) Depths measured from top of well cover unless otherwise noted

(2) Depths measured from top of casing

(3) Ground water elevations reported by GRC (1992) do not match depth/TOC data reported for 5/92.

(4) Well Surveyed (or resurveyed) by Tetra Tech, April 1993.

The water levels were measured a second time on April 8, 1993, just prior to sampling the well network in the Livingston Plaza area. Again, the measurements were made from both the tops of casings, and from the rims of the vaults. The probe was decontaminated by scrubbing in detergent and rinsing with distilled water between wells.

3.3.2 Purging

For those wells from which ground water samples are collected (wells without free product), at least three well volumes were purged prior to sampling, and the indicator parameters of temperature, Ph, and conductivity were measured and recorded to verify, to the extent possible, that the water in the well is representative of the surrounding aquifer. Wells were purged with a Waterra Hydrolift pump, to minimize the possibility of cross-contamination of wells. This pump operates by raising and lowering a rigid length of plastic tubing in the well, fitted with a check valve in the lower end of the tubing. The tubing was either decontaminated or replaced between wells.

Wells were sampled in an order from least contaminated to more contaminated, based on previous observation of the intensity of contamination in the wells. A steam cleaner was used to decontaminate the tubing and other equipment. During the sampling round, the steam cleaner failed, and rather than decontaminate the tubing manually, it was simply discarded and replaced for each well. Purge water and decontamination rinsate was contained in drums near the wells, which were later moved to the fenced drum storage area, or the water was discharged to the sanitary sewer if it met the requirements of the City of Livingston Public Works Department.

3.3.3 Sample Collection

Ground water samples were collected from April 10 to April 13, 1993, allowing more than the minimum 24-hrs between well development and sampling to enable equilibrium to be established in the well and surrounding aquifer.

Sampling protocol was as follows:

Water samples were collected only from wells that did not contain floating gasoline product. After purging the wells, the water samples were collected in a Teflon bailer equipped with a bottom-emptying device, by lowering the bailer slowly below the water surface to fill. Sample was transferred to pre-cleaned sample bottles with minimal turbulence.

Ground water samples were analyzed by the same methods used for the soil samples, including:

- EPA Method 8015, modified, for Total Extractable Hydrocarbons as diesel;
- EPA Method 8015, modified, for Total Volatile Hydrocarbons as gasoline; and,
- EPA Method 8020/602, for Benzene, Toluene, Xylene, and Ethylbenzene.

In addition, ground water samples from wells in the region that contains the floating product plume were analyzed for total lead.

A travel blank was placed in each cooler containing water samples. Travel blanks were prepared in the field from commercial distilled water. The laboratory was instructed to analyze the travel blank for volatile constituents if any of the samples in the cooler shipped with the blank contained detectable concentrations.

3.4 FREE GASOLINE PRODUCT SAMPLING

Product samples were collected on April 8, 1993 from each well in which product was observed, using a disposable Teflon bailer with a bottom-emptying device. Only MW-4, MW-6, MWII-22, and MWII-24 contained product. The bailer was lowered slowly across the water table, allowing product to enter the bailer, along with water. The thickness of the product layer in the bailer was consistent in every case with the thickness measured with the interface probe, although minor differences were noted.

Samples were placed in 40 Ml VOA bottles by allowing the water below the product to drain out of the bailer, to the extent possible, then draining the product into the VOA vial. The VOA vials were

labelled with the number of the well, followed by a "P" designation. The samples were immediately placed in a cooler, on ice, in an inverted position (septum down), so that a layer of water, rather than product, was in contact with the septum of the vial during transport to the laboratory. The product samples were delivered to the laboratory on the day following sampling. The product samples were analyzed by EPA Method 8240 (GC/MS).

4.0 INVESTIGATIVE RESULTS AND FIELD OBSERVATIONS

4.0 INVESTIGATIVE RESULTS AND FIELD OBSERVATIONS

4.1 SITE GEOLOGY

Boring logs from each of the borings and monitoring wells are presented in Appendix A2. It was generally observed that the site is underlain by relatively permeable, sandy materials. The continuous core from CC-3, which represented nearly full recovery, was typical of the vadose zone materials seen throughout the site. Minor variations were observed, such as a coarse gravel lens, at about 20 to 22 ft in CC-2 and BT-6, minor gravel at 30 ft in boring BT-1, and gravelly fill material at a depth of 10 ft in boring MW-30A.

The upper 10 ft is a brown silty sand loam, containing varying amounts of silt. This material may represent the Modesto Formation. The material is not high in humic material, and is friable when dry. It is also soft and less consolidated than the material below it.

At a depth of about 10 there is a sharp contact between the brown silty sand loam and underlying light gray sediments that contain several thin beds of alternating silts and sands. The light gray sediments appear to be derived from granitic materials and may belong to the Riverbank Formation. The color change corresponds with a change in density or compaction, possibly related to an increase in sand content.

The base of the light-gray sediment zone corresponds with the top of a poorly-cemented, apparently iron oxide-rich hard pan about 3 to 4 ft thick. The iron oxide probably originates from weathering of finely-laminated micaceous beds near the top of the hard pan. Cementation includes both iron oxide and a white mineral precipitate, tentatively identified as gypsum. A flame ionization detector (FID) was used to screen samples for gasoline vapor in the field. Low FID readings and lack of observed gasoline odor above about 15 ft (in areas not otherwise associated with a surface spill) suggest that the hard pan acts as an effective barrier to upward migration of gasoline vapor. This vapor barrier 15

apparently the result of both the weak iron oxide and gypsum cementation between grains and the horizontal orientation of mica grains in the thinly laminated silt beds in this zone.

The base of the hard pan is represented by a sharp contact with a generally homogeneous gray fine to coarse silty sand unit at about 20 ft, which extends to a depth of about 50 ft. Within this zone, elevated FID readings and a strong odor of gasoline were frequently observed. However, these elevated FID readings and observed gasoline odor frequently did not correspond with a high concentration of gasoline in the soil sample analyzed by the laboratory. This is interpreted as further evidence that the hard pan zone acts as a barrier to gasoline vapor migration, since the source of the vapor appears to be the gasoline product at the water table that has diffused into the permeable sediments between 20 to 50 ft.

From 20 ft to about 40 ft, the materials consist of well-graded fine to coarse, permeable, lithic-rich sand with occasional brown iron-staining. A thin silt horizon was observed in CC-3 at 39 to 40 ft, but was not observed elsewhere at this depth. This was the depth of the water table in 1989. The degree of sorting generally increases between 40 and about 50 ft, the depth of the present water table. Below 45 ft there is more frequent evidence of bedding, including horizontal orientation of mica grains.

Geologic sections A-A', B-B', and C-C', shown in Figures 4, 5, and 6, respectively, show the interpretation of subsurface geology described above. The locations of the sections are shown on Figure 3.

4.2 SITE HYDROGEOLOGY

Hydrogeological data from previous investigations at the site has been discussed in Section 2.4. The discussion in this section is a continuation of that discussion, and is based on results of the ground water monitoring activities conducted in March and April, 1993.

Table 2 contains a compilation of the water level data obtained by Tetra Tech on March 25, and April 8, 1993. Water level data from previous investigations is also presented for comparison. The data

TABLE 2 GROUND WATER ELEVATIONS (ft, msl)

WELL ID	WELL ELEVATION (1)	ELEVATION BOTTOM OF SCREEN	8/89	1/90	3/90	4/90	6/90	8/90	9/90	4/91	3/92	5/92	7/92	3/25/93 STATIC GW ELEVATION		3/25/93 PRODUCT THICKNESS	4/8/93 STATIC GW ELEVATION		4/8/93 PRODUCT THICKNESS	5/20/93 (7) STATIC GW ELEVATION
MW-1	134.53	83.53	93.15	92.20	91.80	91.50	90.07	88.79	88.15						(6)			(6)		
MW-2	134.56	81.56	93.09	92.11	91.80	91.46	90.01	88.74	88.08											
MW-3	134.73	81.73	93.28	92.21	91.89	91.54	90.12	88.84	88.21											
MW-4	130.17	78.17	(1.5)	(1.66)	(1.31)	(0.18)	(0.31)	(0.34)		(1.29)	(0.03)		(0.18)	82.62		0.06	82.58		0.1	
MW-5	133.11	81.11	91.18	90.58	90.26	89.00	88.50	87.23												
MW-6	132.68	81.18	91.35	(0.08)	(0.46)	(0.39)	(0.58)	(0.36)			(0.015)		(0.08)	82.79		0.015	82.75		0.02	
MW-7	130.66	81.16	90.76	90.36	90.01	89.61	88.20	86.87			84.28		82.33	82.38	(6)		82.31	(6)		
MW-8	132.09	82.59	91.30	90.79	90.51	90.14	88.80	87.63			84.56		83.06	82.80	(5)		82.76	(5)		
MW-9	129.04	79.54	89.21	87.19	86.52	86.26	86.25	86.32												
MW-10	130.07	81.07	89.62	87.54	86.83	86.55	86.55	86.65												
MW-11	128.80	79.8	89.37	87.36	86.67	86.41	86.41	86.50												
MWII-1	132.83	82.83			90.38	90.02	88.65	87.35							(6)			(6)		
MWII-2	132.90	78.9			90.48	90.12	88.75	87.49												
MWII-3	133.04	78.04			90.15	89.77	88.37	87.09												
MWII-4	135.60	80.6			91.74	91.42	90.02	88.70	88.07											
MWII-5 (2)	132.16	77.16			(0.35)	(0.09)	(0.05)	(0.16)		(0.25)	(0.02)		(0.01)	82.77			82.74			
MWII-5 (2.4)	131.63													82.66			82.63			
MWII-6	132.56	77.56			90.66	90.31	89.01	87.80			84.70		83.21	82.93			82.88			
MWII-7	130.55	75.55			90.39	90.01	88.63	87.37		86.60	84.56		84.95	82.76			82.76			
MWII-8	131.05	81.05			90.85	90.51	89.23	88.06			84.90		83.39	no access	(5)		80.40	(5)		
MWII-9	130.62	74.62			90.43	90.06	88.68	87.18			84.59		83.00	82.85			82.83			
MWII-10 (2)	129.59	76.09			90.22	89.81	88.38	87.07			84.45		82.72	82.72			82.68			
MWII-10 (2.4)	129.13													82.56			82.54			
MWII-11	129.99	74.99			90.14	89.72	88.28	86.95		86.40	84.39		82.54	82.57			82.56			
MWII-12	130.46	74.46			90.55	90.18	88.88	87.60			84.66		83.14	82.96			82.93			
MWII-13	128.78	75.78			90.23	89.73	88.32	86.95												
MWII-14	129.30	74.3			90.33	89.91	88.52	87.20			84.50		82.84	82.77			82.75			
MWII-15	129.36	74.36			90.47	90.00	88.61	87.32												
MWII-16	129.42	74.42			90.46	89.97	88.59	87.26												
MWII-17 (2)	129.86	72.86			90.47	90.05	88.66	86.79												
MWII-18	131.36	75.86			89.95	89.50	88.04	86.73			84.30		82.18	82.38			82.35			
MWII-19	132.36	76.86			89.92	89.49	88.06	86.77			84.07		81.74	82.10			81.92			
MWII-20	133.30	78.3			90.34	89.96	88.60	87.37			84.40		82.60	82.55			82.50			
MWII-21	126.92	71.92			86.00	85.77	85.76	85.80												
MWII-22	131.02	79.52			90.43	90.03	(1.45)	(1.31)		(1.15)	(0.38)		(0.68)	82.53		0.35	82.50		0.35	
MWII-23	132.08	82.08			90.87	90.53	89.27	88.12			84.86		83.39	83.14			83.14			
MWII-24	130.32	75.32			(0.73)	(1.60)	(1.88)	(1.87)		(1.33)	(0.86)		(0.78)	81.86		0.88	81.83		0.89	
MWII-25	131.32	78.82			90.53	90.15	88.79	87.51												
MWII-26	130.36	80.36			90.85	89.45	88.01	86.73			84.07		81.94	82.07			82.05			
MWII-27 (2.3)	131.71	73.71										84.24		82.32			82.28			
MWII-27 (2.4)	131.60													82.66			82.63			
MWII-28 (2.3)	132.52	74.52										85.17		83.28			83.21			
MWII-28 (2.4)	131.41													82.61			82.58			
MWII-29 (2.3)	132.14	72.14										84.30		82.51			82.47			

TABLE 2 (Continued) GROUND WATER ELEVATIONS (ft, msl)

WELL ID	WELL ELEVATION (1)	ELEVATION BOTTOM OF SCREEN	8/89	1/90	3/90	4/90	6/90	8/90	9/90	4/91	3/92	5/92	7/92	3/25/93 STATIC GW ELEVATION	3/25/93 PRODUCT THICKNESS	4/8/93 STATIC GW ELEVATION	4/8/93 PRODUCT THICKNESS	5/20/93 (7) STATIC GW ELEVATION
MWII-29 (2,4)	132.03													82.73		82.69		
BS-1	N/A														(5)		(5)	
BS-2	N/A														(5)		(5)	
BS-3	N/A														(5)		(5)	
BL-1	N/A														(5)		(5)	
MWII-30 (2,4)	130.01	71.01														82.78		
MWII-31 (2,4)	130.61	71.61														82.74		
MWII-32 (2,4)	131.35	72.35														82.71		
MWII-33 (2,4)	129.41	70.41														82.59		82.24

Notes:
(1) Depths measured from top of well cover unless otherwise noted.
(2) Depths measured from top of casing.
(3) Ground water elevations reported by GRC (1992) do not match depth/TOC data reported for 5/92.
(4) Resurveyed or new survey of TOC by Tetra Tech 4/8/93.
(5) Water level below screen or screen sump.
(6) Water level may be below bottom of screen.
(7) Resampled.

show that water levels declined about 0.2 ft between July 1992 to March 1993, but remained steady between March, 1993 and April, 1993.

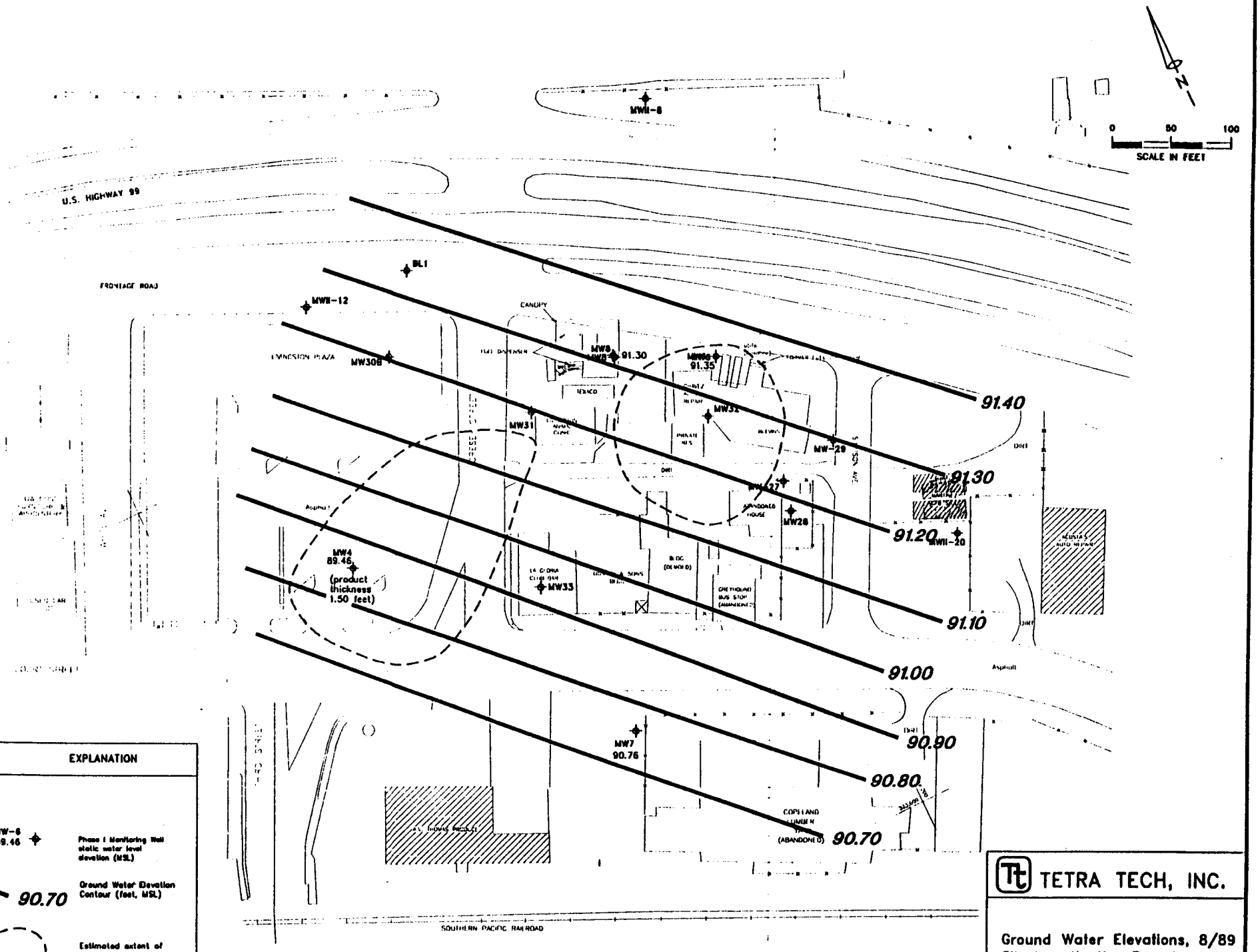
Product thickness in the monitored wells also remained steady during 1993. No product was observed in MWII-5 in March or April of 1993, although it was reported to be present in July, 1992. Water levels were near the bottom of some of the well screens in March and April, 1993, and apparently below the depth of the screens in MW-8 and MWII-8.

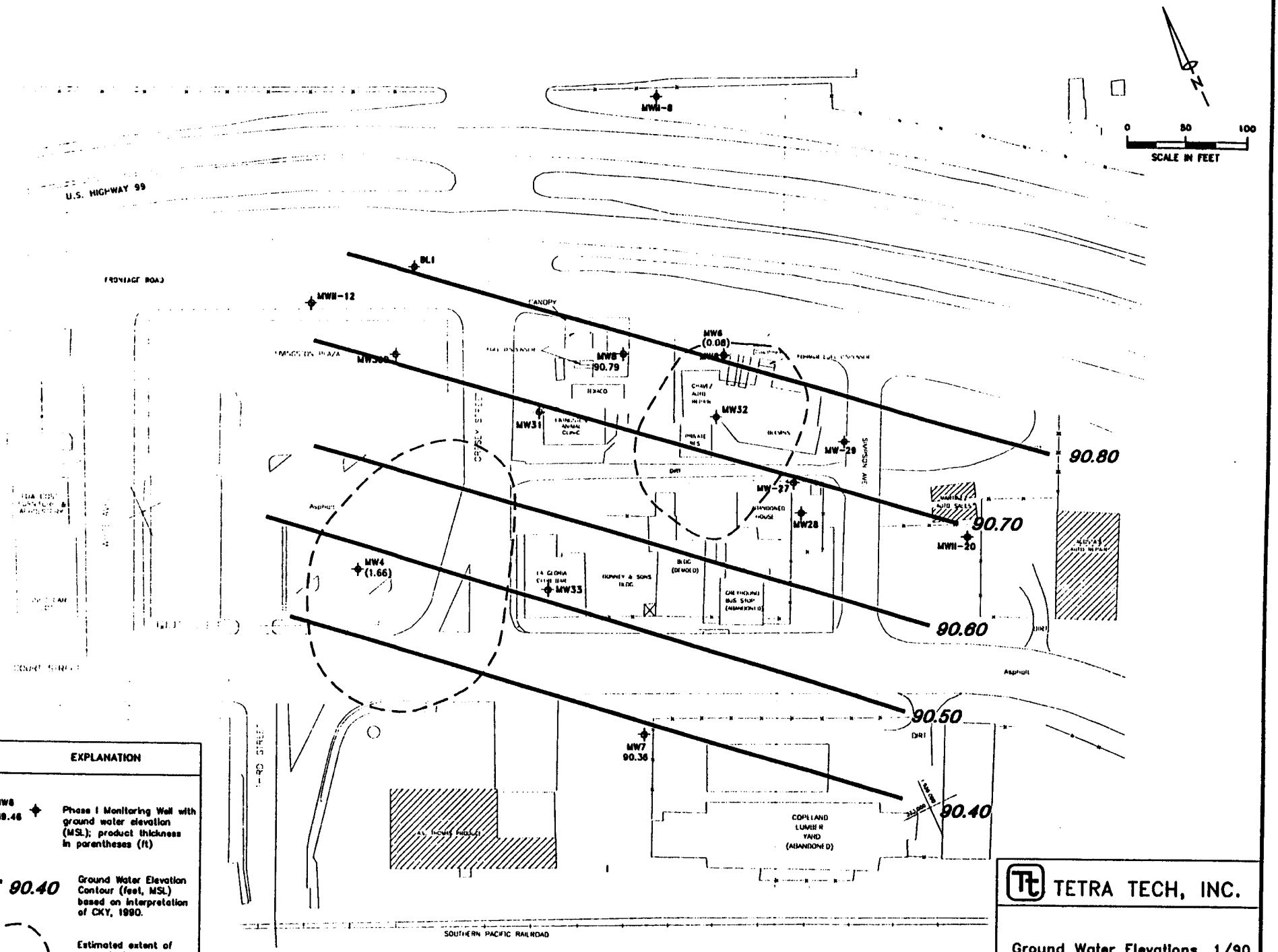
Figures 7 through 13 illustrate the configuration of the water table based on the data presented in Table 2. The water table configurations portrayed in Figures 7 and 8 are based on very limited data from the period, but are consistent with later data. The interpretation shows a gradient to the southwest. The hydraulic gradient shown in Figure 7 is a reinterpretation of the data presented by CKY (1989). At that time, the gradient was interpreted to be toward the west. Of the eleven wells installed in 1989, only MW-4 contained gasoline product, which was reported to be 1.5 ft thick. The thickness of the floating product has apparently decreased. The configuration of the product plume, showing how the plume may have changed during the investigation period, is also shown on the water table maps.

Figures 9 through 13 show how the gradient apparently rotated toward the south as water levels decreased between 1990 to 1992. Figure 10 shows the development of a ground water depression south of MWII-26. Such a depression is characteristic of ground water extraction, and may be related to one or more wells located south of the site. A municipal supply well is located south of the site, but was reportedly shut down in 1992.

In June, 1990, product first began to be observed in MWII-22, giving the appearance that the product plume was migrating northward from MW-4, against the hydraulic gradient. Product thickness in MW-4 was reduced to 0.31 ft, and in MWII-5 it was reduced to 0.05 ft.

By August of 1990, the water table had dropped about 2 ft from its level in April. The data began to show the development of a hydraulic high point (indicative of recharge) in the vicinity of MWII-7 and a trough (suggestive of pumping) in the region of MWII-9 (see Figure 11). During 1990, the City of Livingston's municipal well, W-4, was shut down due to contamination by DBCP.

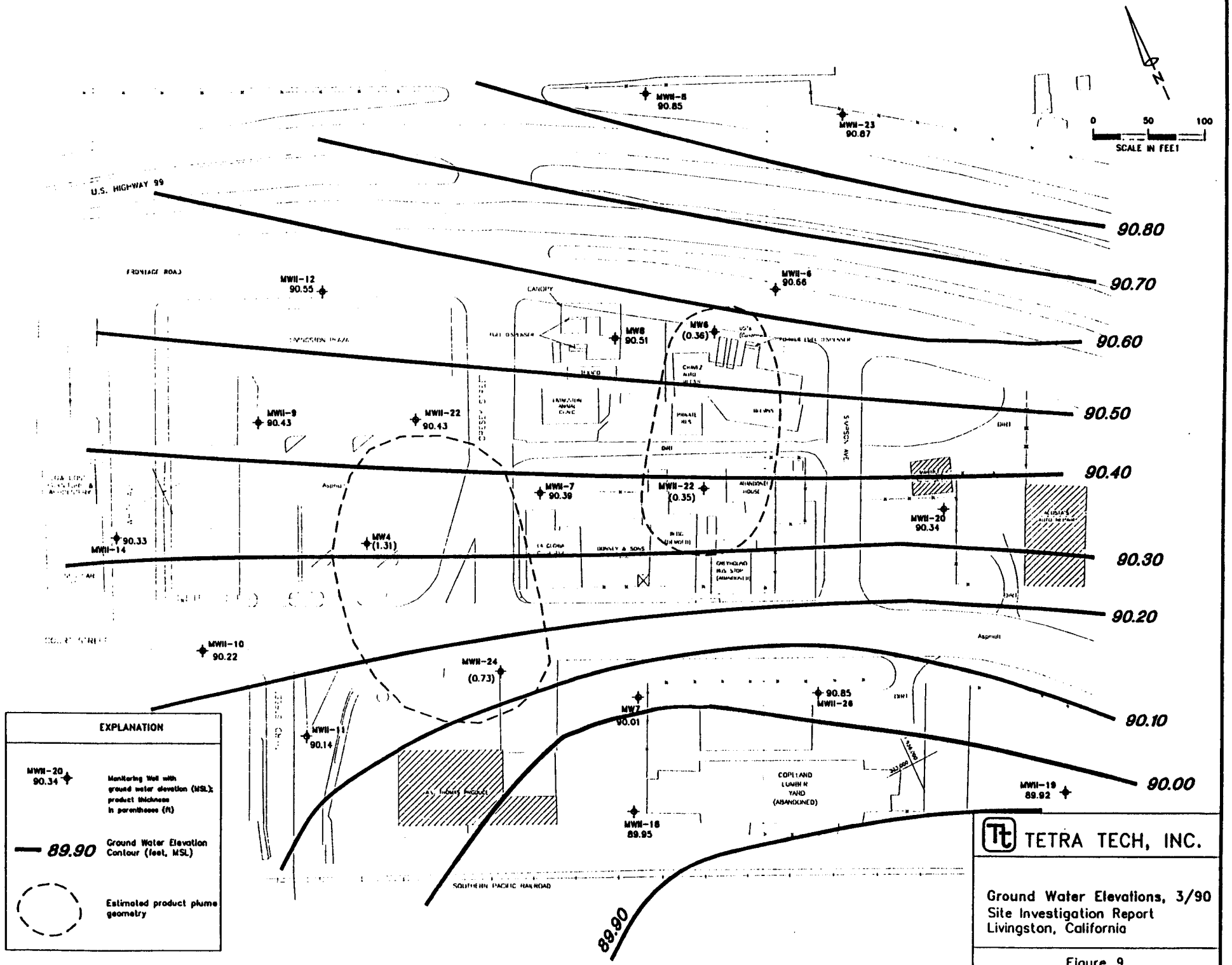

U.S. HIGHWAY 99
FRONTAGE ROAD
MW11-8
MW11-12
BL1
MW30B
MW8
91.30
MW9
91.35
MW31
MW32
MW-29
MW27
MW28
MW11-20
MW4
89.46
(product thickness 1.50 feet)
MW33
MW7
90.76
91.40
91.30
91.20
91.10
91.00
90.90
90.80
90.70
SOUTHERN PACIFIC RAILROAD
0
50
100
SCALE IN FEET
EXPLANATION
MW-6 89.46
Phase I Monitoring Well static water level elevation (MSL)
90.70
Ground Water Elevation Contour (feet, MSL)
Estimated extent of product plume
TETRA TECH, INC.
Ground Water Elevations, 8/89
Site Investigation Report
Livingston, California
Figure 7

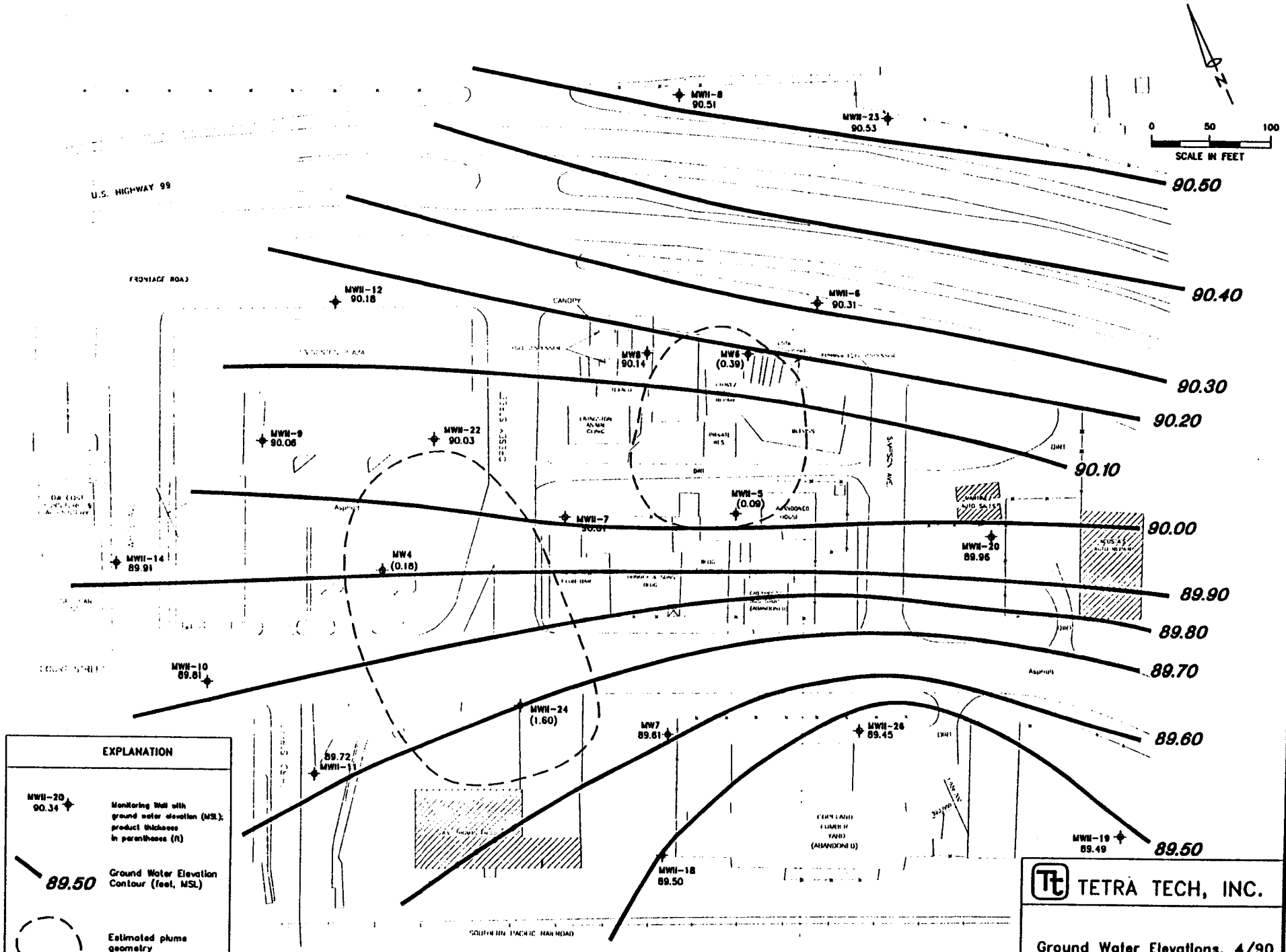


TETRA TECH, INC.

Ground Water Elevations, 1/90
Site Investigation Report
Livingston, California

Figure 8

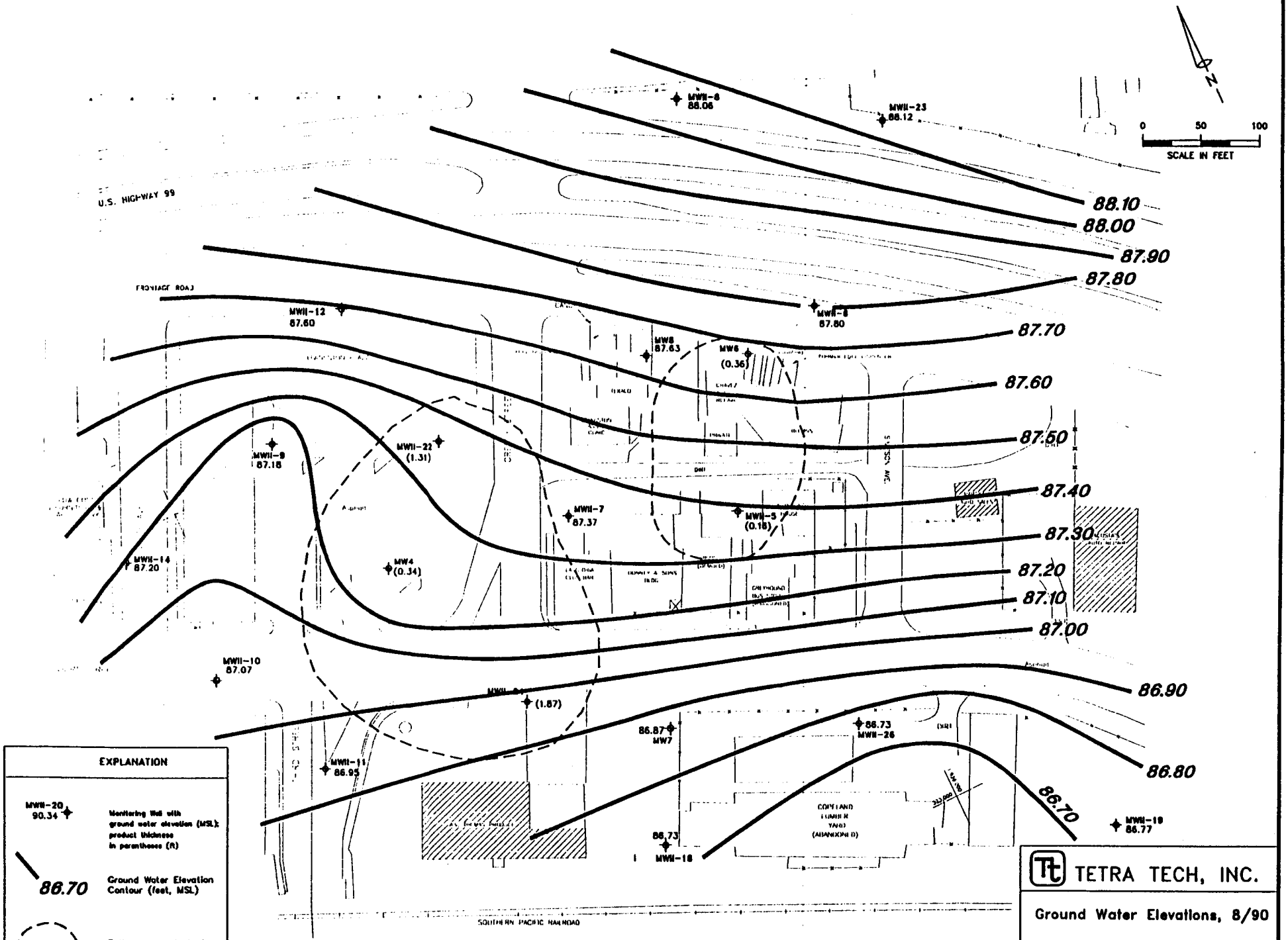

N
0 50 100
SCALE IN FEET
U.S. HIGHWAY 99
FRONTAGE ROAD
MWII-5 90.85
MWII-23 90.87
MWII-12 90.55
MWII-6 90.66
MW8 90.51
MW6 (0.36)
MWII-9 90.43
MWII-22 90.43
MWII-7 90.39
MWII-22 (0.35)
MWII-20 90.34
MWII-14 90.33
MW4 (1.31)
MWII-10 90.22
MWII-24 (0.73)
MW7 90.01
90.85 MWII-26
MWII-11 90.14
MWII-19 89.92
MWII-18 89.95
COPELAND LUMBER YARD (ABANDONED)
SOUTHERN PACIFIC RAILROAD
90.80
90.70
90.60
90.50
90.40
90.30
90.20
90.10
90.00
89.90
EXPLANATION
MWII-20 90.34 Monitoring Well with ground water elevation (MSL); product thickness in parentheses (ft)
89.90 Ground Water Elevation Contour (feet, MSL)
Estimated product plume geometry
TETRA TECH, INC.
Ground Water Elevations, 3/90
Site Investigation Report
Livingston, California
Figure 9



TETRA TECH, INC.

Ground Water Elevations, 4/90
Site Investigation Report
Livingston, California

Figure 10

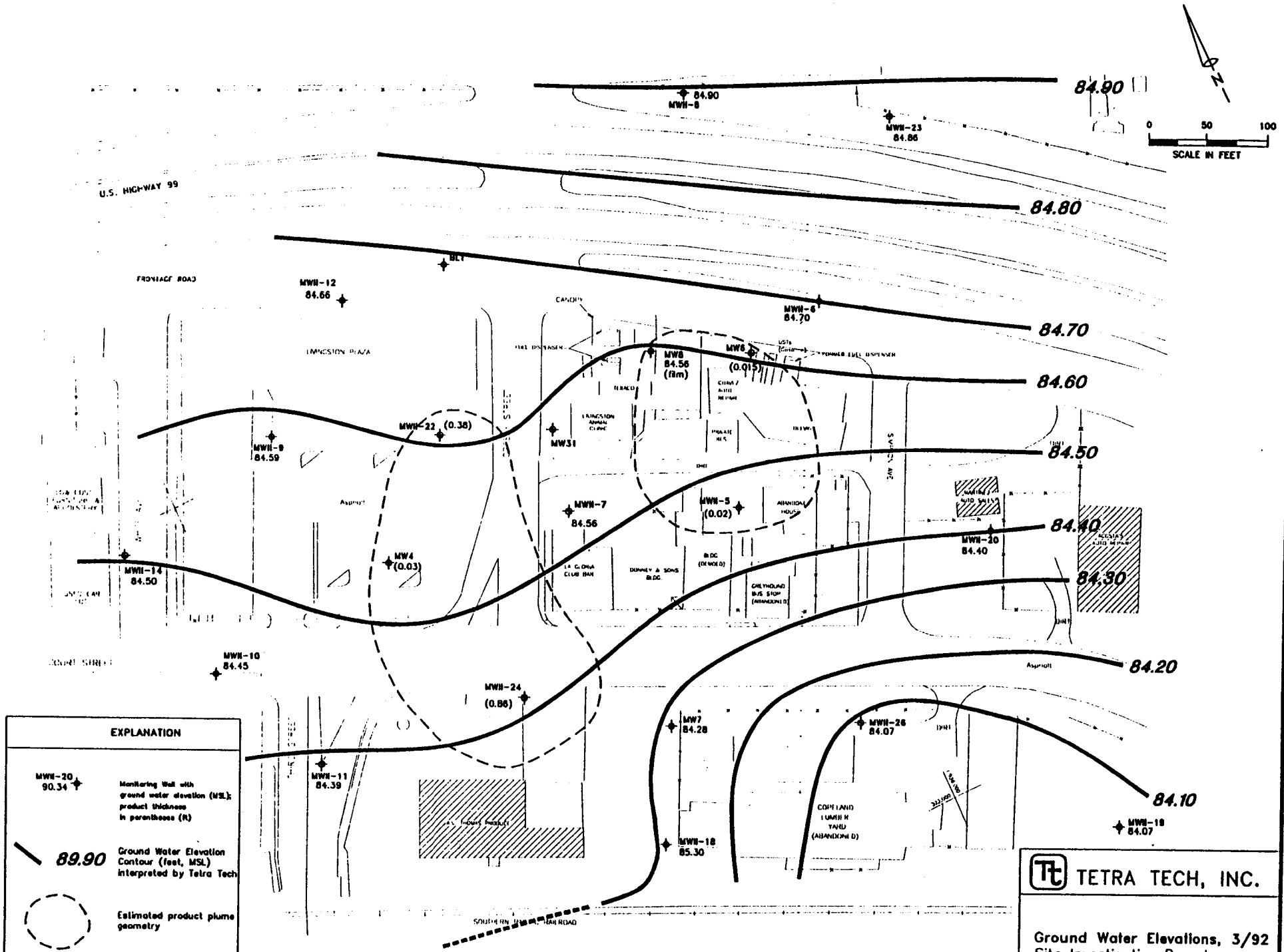


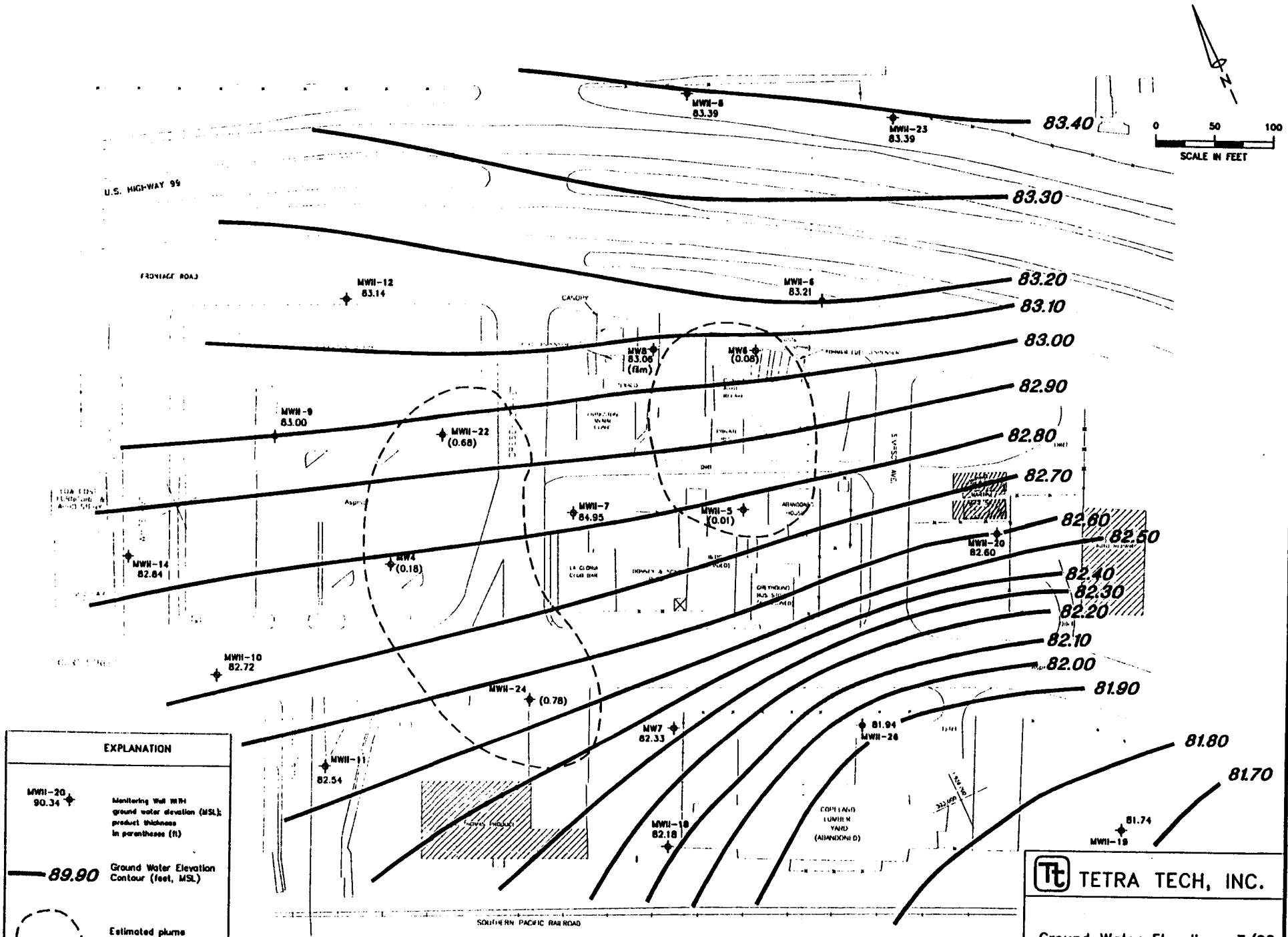
TETRA TECH, INC.

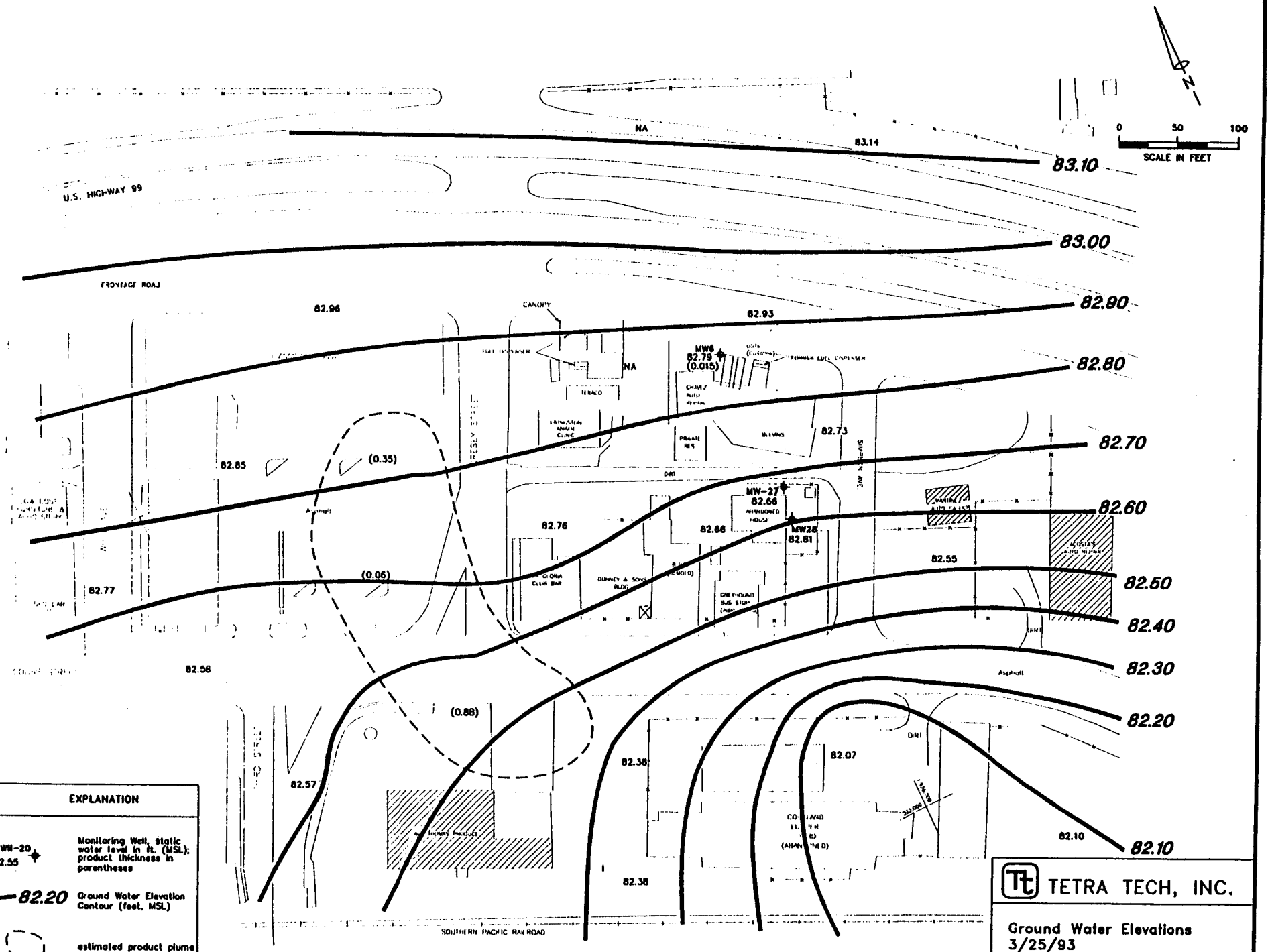
Ground Water Elevations, 8/90

Site Investigation Report
Livingston, California

Figure 11


84.90
84.80
84.70
84.60
84.50
84.40
84.30
84.20
84.10
MWH-8
84.90
MWH-23
84.86
MWH-12
84.66
MWH-6
84.70
MW8
84.56
(film)
MW6
(0.015)
MWH-22 (0.38)
MWH-9
84.59
MW31
MWH-7
84.56
MWH-5
(0.02)
MWH-20
84.40
MWH-14
84.50
MW4
(0.03)
MWH-10
84.45
MWH-24
(0.86)
MWH-11
84.39
MW7
84.28
MWH-26
84.07
MWH-18
85.30
MWH-19
84.07
U.S. HIGHWAY 99
FRONTAGE ROAD
EMMISSION PLAZA
SCALE IN FEET
0
50
100
N
EXPLANATION
MWH-20
90.34
Monitoring Well with ground water elevation (MSL); product thickness in parentheses (ft)
89.90
Ground Water Elevation Contour (feet, MSL) interpreted by Tetra Tech
Estimated product plume geometry
TETRA TECH, INC.
Ground Water Elevations, 3/92
Site Investigation Report
Livingston, California
Figure 12


N
0 50 100
SCALE IN FEET
U.S. HIGHWAY 99
FRONTAGE ROAD
SOUTHERN PACIFIC RAILROAD
MWH-8 83.39
MWH-23 83.39
MWH-12 83.14
MWH-6 83.21
MW3 83.06 (film)
MW5 (0.08)
MWH-9 83.00
MWH-22 (0.68)
MWH-7 84.95
MWH-5 (0.01)
MWH-14 82.84
MW4 (0.18)
MWH-20 82.60
MWH-10 82.72
MWH-24 (0.78)
MW7 82.33
MWH-26 81.94
MWH-11 82.54
MWH-18 82.18
MWH-19 81.74
83.40
83.30
83.20
83.10
83.00
82.90
82.80
82.70
82.60
82.50
82.40
82.30
82.20
82.10
82.00
81.90
81.80
81.70
EXPLANATION
MWH-20 90.34
Monitoring Well With ground water elevation (MSL); product thickness in parentheses (ft)
89.90
Ground Water Elevation Contour (feet, MSL)
Estimated plume geometry
TETRA TECH, INC.
Ground Water Elevations, 7/92
Site Investigation Report
Livingston, California
Figure 13

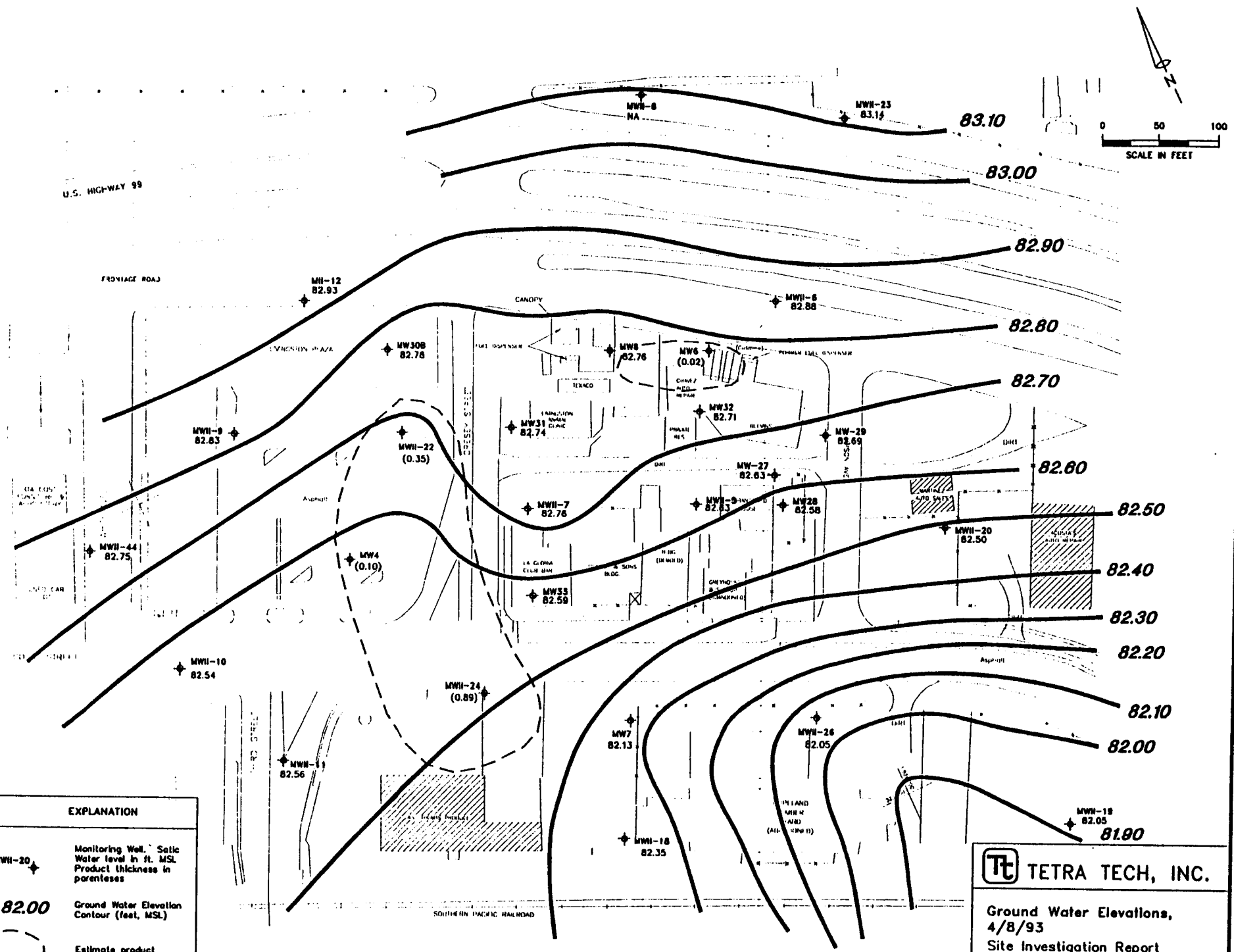

N
0 50 100
SCALE IN FEET
U.S. HIGHWAY 99
FRONTAGE ROAD
SOUTHERN PACIFIC RAILROAD
CANOPY
NA
83.14
83.10
83.00
82.90
82.80
82.70
82.60
82.50
82.40
82.30
82.20
82.10
82.96
82.93
82.85
82.79
(0.015)
MW6
82.73
(0.35)
82.76
82.66
MW-27
82.66
ABANDONED
MW26
82.61
82.77
(0.06)
82.55
82.56
(0.88)
82.57
82.36
82.07
82.38
Asphalt
DRT
EXPLANATION
MW1-20
82.55
Monitoring Well, static water level in ft. (MSL); product thickness in parentheses
82.20
Ground Water Elevation Contour (feet, MSL)
estimated product plume geometry
TETRA TECH, INC.
Ground Water Elevations
3/25/93
Site Investigation Report
Livingston, California
Figure 14

Water levels in four wells were measured in September, 1990, and indicated that water levels were continuing their decreasing trend. In April 1991, product thickness was measure in selected wells, and indicated a significant increase in MW-4 (now 1.29 ft), with less variation in other wells.

In March of 1992, 19 months after the previous complete monitoring round, the water table had declined about 3 ft, according to data reported by Krazan & Associates during a sampling round in which product samples were collected for Chevron. Figure 12 indicates that an anomalously high water table near MWII-7 remained in place from the previous round of water level measurements. Product thickness appeared to have generally decreased in all wells. A product film was reported in MW-8 for the first time. (Note that measurements of product thickness were made with a bailer prior to 1992 and with an interface probe beginning in 1992).

The July, 1992 water level data indicate a ground water mound in the area of MWII-7 (Figure 13). The reported water level in MWII-7 is anomalous, since it is approximately 0.4 ft higher than it was in March, although surrounding wells showed declines of 1.5 to 2 ft. Water levels generally declined about 7.5 ft between August, 1989 and July 1992. Product thickness increased by 0.3 ft in MWII-22, with minor fluctuations in other wells since the previous sampling round.

Figure 14 shows the configuration of the water table based on March 1993 data. MW-30 through MW-33 were installed after the water levels were measured in March, 1993. Figure 15 indicates that there is a slight anomalous mounding on the water table in the vicinity of MWII-7. A pronounced depression is present south of MWII-19. Comparison with Figures 3 through 9 indicates that the depression appears to be shifting to the east. Figure 15 shows that in the region where floating product is thickest, west of Cressey Street, there is an appearance of a trough, which bends to the east near MWII-24. There are inadequate data north of the site to evaluate the direction of the gradient in that area. However, in the recent past, ground water coming onto the site appears to be moving toward the southwest.



TETRA TECH, INC.

Ground Water Elevations, 4/8/93
Site Investigation Report
Livingston, California

Figure 15

4.3 SOIL SAMPLE ANALYTICAL RESULTS

Soil analytical results for BTEX, TPH-G, and TPH-D are summarized in Table 3. Copies of laboratory reports are presented in Appendix C1. (Soil sample results for TPH-g that were above the detection limit in borings located along the lines of geologic sections are plotted on Figures 4, 5, and 6).

Diesel was reported in most of the soil and ground water samples in which gasoline was reported. The "diesel" results require clarification. Further evaluation of the chromatogram for these samples suggests that the petroleum hydrocarbon mixture reported as diesel was a weathered gasoline in which some of the constituent components fall within the diesel range and were objectively reported by the laboratory as diesel. The laboratory was requested to provide further interpretation of the chromatogram, and they concluded that the chromatogram are characteristic of gasoline, and not diesel. A brief report of the findings was made by the laboratory to this effect and is presented in Appendix C2. Their interpretation of the chromatogram is consistent with previous laboratory analysis. Some of the results reported by Krazan and Associates from samples collected from the former Livingston Mini Mart and Chavez Auto Repair sites may also have been gasoline that falls within the diesel range.

One of the noteworthy results indicated by a comparison of Table 2 and the FID readings recorded on the boring logs in Appendix A2 is that in many borings, high FID readings were not necessarily correlated with elevated TPH-G concentrations reported by the laboratory in the soil samples. As mentioned earlier, this phenomenon may be explained by diffusion of gasoline vapor from floating product on the water table into the porous sandy material in the 30 ft interval between the water table and the hard pan. The reason that the FID readings are not diagnostic of a significant gasoline concentration in the soil itself requires a brief explanation.

If gasoline is spilled on soil, some of it will vaporize in the pore space, some of it will flow through the soil by gravity, and the remainder will adhere to the soil. It is this portion that adheres to the soil that gets detected by laboratory analysis of the soil. The amount of gasoline present in the vapor phase is only limited by Raoult's Law, which describes the amount of vapor in equilibrium with a volatile liquid. Soil humidity tends to decrease the amount of gasoline that can volatilize in the pore space, since water vapor molecules compete with gasoline molecules for space in the soil pores. Some of the gasoline vapor which diffuses through the soil porosity may sorb to soil particles. The equilibrium partitioning between

TABLE 3 SOIL SAMPLE RESULTS FROM LIVINGSTON FREEWAY

Sample ID	Lab ID	Date Sampled	Date Analyzed	Depth (Ft)	Method 8015 TPH-G (mg/kg)	Method 8015 TPH-D (mg/kg)	Method 8020 Benzene (ug/kg)	Method 8020 Toluene (ug/kg)	Method 8020 Ethylben (ug/kg)	Method 8020 p-,m-Xylenes (ug/kg)	Method 8020 o-Xylene (ug/kg)	Remarks
BT1-5B	4-09705	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-10B	4-09706	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-15B	4-09707	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-17B	4-09708	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-20B	4-09709	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-25B	4-097010	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-30B	4-097011	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-32B	4-097012	3/29/93			NA	NA	NA	NA	NA	NA	NA	sample held
BT1-35B	4-097013	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-37B	4-097014	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-40B	4-097015	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-45B	4-097016	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT1-48B	4-097017	3/29/93			NA	NA	NA	NA	NA	NA	NA	sample held
BT2-5B	4-097018	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-10B	4-097019	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-15B	4-097020	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-20B	4-097021	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-25B	4-097022	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-30B	4-097023	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-32B	4-097024	3/29/93			NA	NA	NA	NA	NA	NA	NA	sample held
BT2-35B	4-097025	3/29/93	4/12-14/93		7.9	57.8	ND	ND	ND	28	18	
BT2-37B	4-097026	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-41B	4-097027	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-45B	4-097028	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT2-47B	4-097029	3/29/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
BT3-5B	4-09767	4/5/93	4/15-18/93		ND	ND	ND	13	ND	ND	ND	
BT3-10B	4-09768	4/5/93	4/15-18/93		6	2.3	26	560	ND	50	11	
BT3-14B	4-09769	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT3-16B	4-09770	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT3-19B	4-09771	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT3-24B	4-09772	4/5/93	4/15-18/93		ND	ND	ND	17	ND	ND	ND	
BT3-29B	4-09773	4/5/93	4/15-18/93		ND	ND	ND	25	ND	ND	ND	
BT3-32B	4-09774	4/5/93	4/15-18/93		1.6	9.5	ND	36	ND	ND	ND	
BT3-38B	4-09775	4/5/93	4/15-18/93		ND	ND	ND	58	ND	30	ND	
BT3-43B	4-09776	4/5/93	4/15-18/93		1.4	8.6	ND	28	ND	ND	ND	
BT3-48B	4-09777	4/5/93	4/15-18/93		ND	2.7	ND	22	ND	ND	ND	

TABLE 3, (Continued) SOIL SAMPLE RESULTS FROM LIVINGSTON FREEWAY

Sample ID	Lab ID	Date Sampled	Date Analyzed	Depth (Ft)	Method 8015 TPH-G (mg/kg)	Method 8015 TPH-D (mg/kg)	Method 8020 Benzene (ug/kg)	Method 8020 Toluene (ug/kg)	Method 8020 Ethylben (ug/kg)	Method 8020 p-,m-Xylenes (ug/kg)	Method 8020 o-Xylene (ug/kg)	Remarks
BT4-5B	4-09778	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT4-10B	4-09779	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT4-14B	4-09780	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT4-17B	4-09781	4/5/93	4/15-18/93		1720	11000	207	10100	6230	38500	20500	
BT4-20B	4-09782	4/5/93	4/15-18/93		4.6	35.2	ND	18	ND	ND	ND	
BT4-22B	4-09783	4/5/93	4/15-18/93		1.3	10.4	ND	12	ND	ND	ND	
BT4-27B	4-09784	4/5/93	4/15-18/93		ND	5.2	ND	ND	ND	ND	ND	
BT4-32B	4-09785	4/5/93	4/15-18/93		2.2	21.8	ND	ND	ND	ND	ND	
BT4-37B	4-09786	4/5/93	4/15-18/93		3.2	20.8	ND	40	ND	ND	ND	
BT4-43B	4-09787	4/5/93	4/15-18/93		1.5	12.4	ND	20	ND	ND	ND	
BT4-48.5B	4-09788	4/5/93	4/15-18/93		ND	ND	ND	55	ND	ND	ND	
BT5-5B	4-09789	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT5-10B	4-09790	4/5/93	4/15-18/93		ND	ND	ND	35	ND	ND	ND	
BT5-13B	4-09791	4/5/93	4/15-18/93		3780	22100	853	73600	30700	183000	93800	
BT5-16B	4-09792	4/5/93	4/15-18/93		3400	17100	3750	137000	35400	167000	74000	
BT5-21B	4-09793	4/5/93	4/15-18/93		2510	16000	454	57700	24800	126000	57900	
BT5-23B	4-09794	4/5/93	4/15-18/93		2540	16000	1710	82600	24900	127000	56700	
BT5-28B	4-09795	4/5/93	4/15-18/93		1480	8220	445	39600	13700	73100	32200	
BT5-33B	4-09796	4/5/93	4/15-18/93		2780	14500	2240	97200	27800	1350000	60400	
BT5-38B	4-09797	4/5/93	4/15-18/93		1920	10100	1380	62800	17400	89100	38800	
BT5-42B	4-09798	4/5/93	4/15-18/93		1850	9300	2990	74000	17200	87500	37800	
BT5-46.5B	4-09799	4/5/93	4/15-18/93		1.8	13.3	ND	ND	ND	ND	ND	
BT6-5B	4-09800	4/5/93	4/15-18/93		ND	4.3	ND	ND	ND	ND	ND	
BT6-10B	4-09801	4/5/93	4/15-18/93		ND	ND	ND	21	ND	ND	ND	
BT6-14B	4-09802	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT6-18B	4-09803	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT6-22B	4-09804	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT6-24B	4-09805	4/5/93	4/15-18/93		ND	ND	ND	10	ND	ND	ND	
BT6-29B	4-09806	4/5/93	4/15-18/93		29.8	200	ND	ND	ND	ND	ND	
BT6-34B	4-09807	4/5/93	4/15-18/93		ND	3.8	ND	33	ND	ND	ND	
BT6-39B	4-09808	4/5/93	4/15-18/93		221	1440	ND	425	923	7840	3910	
BT6-46B	4-09809	4/5/93	4/15-18/93		ND	ND	ND	ND	ND	ND	ND	
BT7-5B	4-09810	4/6/93	4/18-20/93		1.8	20.6	ND	ND	ND	24	18	
BT7-10B	4-09811	4/6/93	4/18-20/93		57.3	400	ND	ND	ND	60	219	
BT7-13B	4-09812	4/6/93	4/18-20/93		2960	19000	ND	2840	ND	85100	65400	
BT7-16B	4-09813	4/6/93	4/18-20/93		734	4890	69	9440	4410	29500	16300	
BT7-21B	4-09814	4/6/93	4/18-20/93		2800	17600	549	68900	22100	107000	63500	
BT7-23B	4-09815	4/6/93	4/18-20/93		547	3520	246	9550	4610	25200	13200	
BT7-28B	4-09816	4/6/93	4/18-20/93		129	851	49	1840	1200	6340	3190	
BT7-33B	4-09817	4/6/93	4/18-20/93		828	5110	834	20000	8980	35900	19600	
BT7-38B	4-09818	4/6/93	4/18-20/93		808	5090	214	9390	7960	33300	17800	
BT7-42B	4-09819	4/6/93	4/18-20/93		1030	6610	ND	5170	8840	38400	21400	
BT7-46B	4-09820	4/6/93	4/18-20/93		48.9	351	10	98	68	300	178	

TABLE 3, (Continued) SOIL SAMPLE RESULTS FROM LIVINGSTON FREEWAY

Sample ID	Lab ID	Date Sampled	Date Analyzed	Depth (Ft)	Method 8015 TPH-G (mg/kg)	Method 8015 TPH-D (mg/kg)	Method 8020 Benzene (ug/kg)	Method 8020 Toluene (ug/kg)	Method 8020 Ethylben (ug/kg)	Method 8020 p-,m-Xylenes (ug/kg)	Method 8020 o-Xylene (ug/kg)	Remarks
BT8-5B	4-09821	4/6/93	4/18-20/93		12.4	98.8	ND	ND	ND	45	20	
BT8-10B	4-09822	4/6/93	4/18-20/93		5.7	48.1	ND	ND	ND	ND	ND	
BT8-14B	4-09823	4/6/93	4/18-20/93		3	27.7	ND	ND	ND	ND	ND	
BT8-16B	4-09824	4/6/93	4/18-20/93		2140	13600	ND	17200	3440	120000	69220	
BT8-19B	4-09825	4/6/93	4/18-20/93		4490	28300	244	73600	63600	220000	142000	
BT8-22B	4-09826	4/6/93	4/18-20/93		355	2280	136	4850	3790	19400	10300	
BT8-27B	4-09827	4/6/93	4/18-20/93		248	1580	89	1840	2140	10400	5720	
BT8-32B	4-09828	4/6/93	4/18-20/93		436	2750	280	5950	4340	18200	10500	
BT8-37B	4-09829	4/6/93	4/18-20/93		1480	9120	1120	17300	14600	53700	31300	
BT8-42B	4-09830	4/6/93	4/18-20/93		91.6	604	92	647	733	3530	1650	
BT8-47B	4-09831	4/6/93	4/18-20/93		18.7	150	53	139	32	106	64	
MW30-5B	4-09692	3/30/93			NA	NA	NA	NA	NA	NA	NA	sample held
MW30-10B	4-09693	3/30/93			NA	NA	NA	NA	NA	NA	NA	sample held
MW30-15B	4-09694	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-16B	4-09695	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-20B	4-09696	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-25B	4-09697	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-32B	4-09698	3/30/93			NA	NA	NA	NA	NA	NA	NA	sample held
MW30-35B	4-09699	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-36B	4-09700	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-37B	4-09701	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-40B	4-09702	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-45B	4-09703	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW30-48B	4-09704	3/30/93	4/12-14/93		ND	ND	ND	ND	ND	ND	ND	
MW31-5B	4-09745	4/1/93	4/12-16/93		1.7	10.7	ND	ND	ND	104	46	
MW31-10B	4-09746	4/1/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW31-15B	4-09747	4/1/93	4/12-16/93		ND	ND	ND	16	ND	ND	ND	
MW31-20B	4-09748	4/1/93	4/12-16/93		ND	3.1	ND	18	ND	24	ND	
MW31-25B	4-09749	4/1/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW31-30B	4-09750	4/1/93	4/12-16/93		ND	2.2	ND	12	ND	12	ND	
MW31-35B	4-09751	4/1/93	4/12-16/93		3	21.2	ND	13	ND	25	15	
MW31-40B	4-09752	4/1/93	4/12-16/93		ND	4.5	ND	ND	ND	ND	ND	
MW31-45B	4-09763	4/1/93	4/12-16/93		ND	3.3	ND	10	ND	ND	ND	
MW31-48B	4-09753	4/1/93	4/12-16/93		1.5	9.9	ND	15	ND	17	ND	

TABLE 3, (Continued) SOIL SAMPLE RESULTS FROM LIVINGSTON FREEWAY

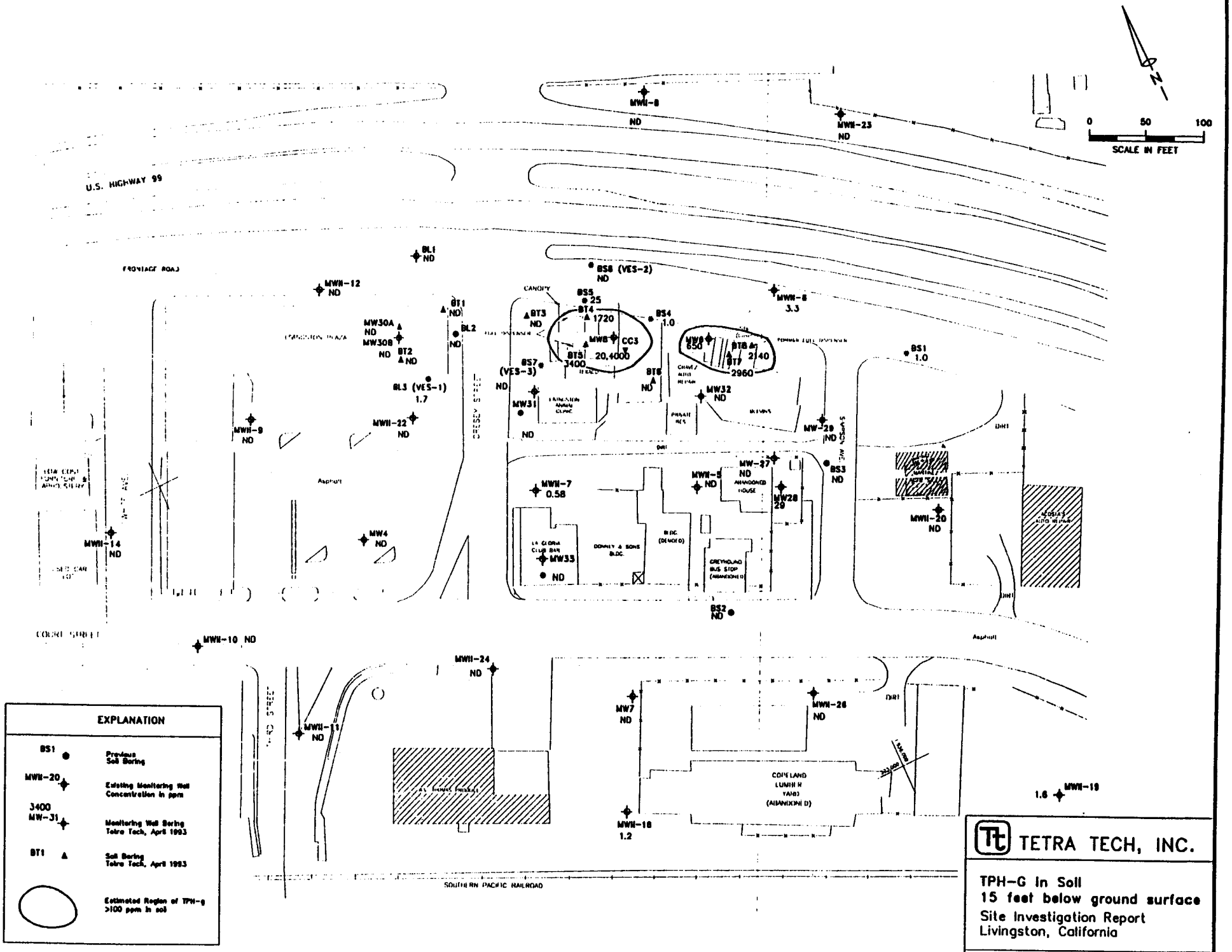
Sample ID	Lab ID	Date Sampled	Date Analyzed	Depth (Ft)	Method 8015 TPH-G (mg/kg)	Method 8015 TPH-D (mg/kg)	Method 8020 Benzene (ug/kg)	Method 8020 Toluene (ug/kg)	Method 8020 Ethylben (ug/kg)	Method 8020 p-,m-Xylenes (ug/kg)	Method 8020 o-Xylene (ug/kg)	Remarks
MW32-5B	4-09733	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-10B	4-09734	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-14B	4-09735	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-16B	4-09736	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-20B	4-09737	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-25B	4-09738	4/2/93	4/12-16/93		ND	ND	ND	11	ND	ND	ND	
MW32-30B	4-09739	4/2/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	
MW32-34B	4-09740	4/2/93	4/12-16/93		ND	3.4	ND	10	ND	12	ND	
MW32-40B	4-09741	4/2/93	4/12-16/93		8.9	61.5	ND	22	ND	49	31	
MW32-41B	4-09742	4/2/93	4/12-16/93		1.8	14.7	ND	11	ND	14	ND	
MW32-45B	4-09743	4/2/93	4/12-16/93		ND	5.7	ND	ND	ND	ND	ND	
MW32-47B	4-09744	4/2/93	4/12-16/93		ND	2.1	ND	ND	ND	ND	ND	
MW33-5B	4-09754	4/1/93	4/12-16/93		827	4650	787	13900	4930	18500	10700	
MW33-10B	4-09755	4/1/93	4/12-16/93		5.4	44.1	ND	11	ND	12	ND	
MW33-15B	4-09756	4/1/93	4/12-16/93		1.8	18	ND	ND	ND	ND	ND	
MW33-20B	4-09757	4/1/93	4/12-16/93		ND	9.5	ND	19	ND	ND	ND	
MW33-25B	4-09758	4/1/93	4/12-16/93		ND	5.4	ND	ND	ND	ND	ND	
MW33-30B	4-09759	4/1/93	4/12-16/93		ND	4	ND	10	ND	ND	ND	
MW33-35B	4-09760	4/1/93	4/12-16/93		ND	5	ND	ND	ND	ND	ND	
MW33-40B	4-09761	4/1/93	4/12-16/93		ND	3.8	ND	11	ND	ND	ND	
MW33-45B	4-09762	4/1/93	4/12-16/93		ND	ND	ND	ND	ND	ND	ND	

NA = not analyzed
ND = not detected

the soil (adsorbed) and vapor (desorbed) phases is described by an equilibrium partitioning constant. For volatile substances of low molecular weight, such as gasoline, equilibrium favors the vapor phase side of the equation. The more natural organic material there is present in the soil, and the smaller the soil particle size, the more gasoline will be adsorbed. However, the soil at the Livingston site probably does not contain much natural organic material. Thus, although the concentration of vapor phase gasoline, whether in equilibrium with liquid gasoline in the sample being tested or in equilibrium with gasoline on the water table 30 ft away, will be controlled only by Raoult's Law and the rate of vapor diffusion through the soil. The high soil vapor concentrations observed in locations that are distant from the source of the contamination are not necessarily associated with a detectable soil phase gasoline concentration.

Major exceptions to the general non-detection of TPH-G in vadose zone soils throughout the site can be seen in the sample results from BT5, BT7, and BT8. BT5 is presumed to be located adjacent to a former fuel dispenser on the Livingston Mini Mart site at 1410 Highway 99. BT7 and BT8 are located over the site of the former underground storage tanks and dispenser island, respectively, at the Chavez Auto Repair site (1444 Highway 99). The occurrence of TPH-G in high concentrations throughout the soil column is an indication of proximity to a source of a release. At some locations isolated elevated concentrations were detected in soil samples at various depths above the water table (for example a concentration of 1720 mg/kg in sample BT4-17B from a depth of 17 ft is bracketed by samples with TPH-G concentrations of less than 5 mg/kg). This suggests that gasoline has migrated horizontally away from the source along some stratigraphically-preferred pathway, but that BT-4 is relatively remote from the source, since the vertical distribution of the gasoline is highly variable. The closer to the source, the more the vertical distribution can be expected to display a continuous pattern.

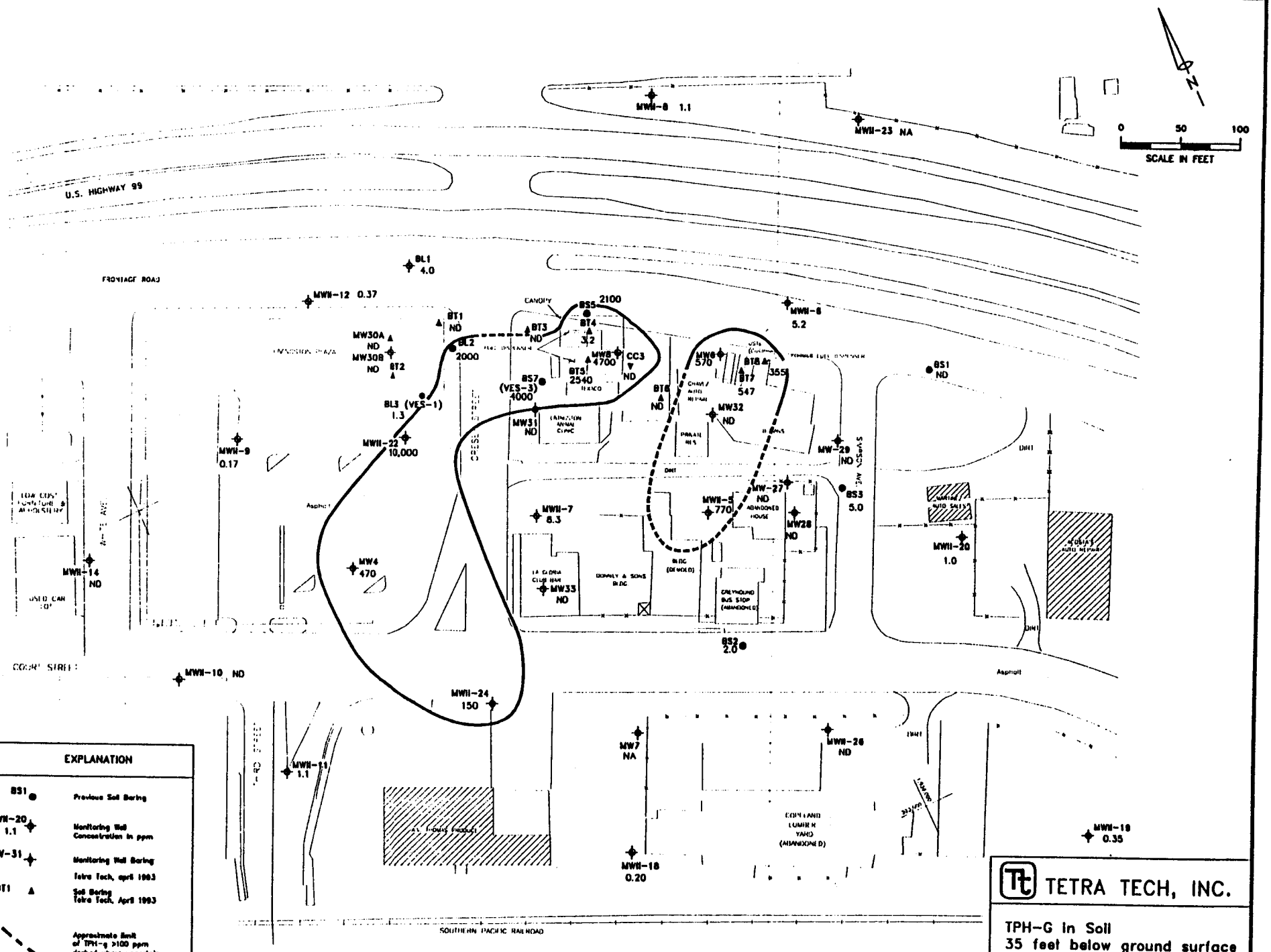
At some locations, elevated concentrations were detected only in the deepest samples (for example, BT6-39B, or BT2-35B), indicating that the detected contamination may have migrated to the location horizontally along the water table. Figures 16 and 17 show the locations of elevated concentrations of TPH-G in soils at 15 ft BGS and at 35 ft BGS, respectively. Results from previous investigations are also incorporated in the figures. The results plotted on Figure 17 west of Cressey Street from previous investigations suggest an association with the floating product plume configuration, rather than with a near-surface source. The water table was probably in the 35 ft depth range a few years before the investigation was initiated at the site in 1989.



TETRA TECH, INC.

TPH-G In Soil
15 feet below ground surface
Site Investigation Report
Livingston, California

Figure 16



TETRA TECH, INC.

TPH-G in Soil
35 feet below ground surface
Site Investigation Report
Livingston, California

Figure 17

4.4 GROUND WATER RESULTS

4.4.1 Water Level Measurement Observations

Water level measurements were collected over a period of about 7 hours on March 25th. However, diurnal water level fluctuations are apparently insignificant, since remeasurement of the water level in MWII-23 at the end of the day confirmed that there had been no change in the water levels over the 7-hour period.

Well MW-8 was inaccessible because the lock on the well cap could not be opened. A number of repairs were needed at wellheads, which were noted in the field log included in Appendix A1. Among the problems requiring attention, the vault of MWII-10 was discovered to be broken, making measurements to the top of the vault inaccurate. This well was later resurveyed to determine the elevation to the top of casing. The data in Table 2 show that water levels are near or below the bottom of the screen in some of the wells. Unfortunately, this may not be perceived when measuring water levels since water may be held in the short sump at the bottom of most wells. The sump usually extends 3 to 6-inches below the screen section. Future monitoring must consider this in order to avoid using the data in compiling water table maps.

The water level measurements taken in March, 1993, confirmed that the water table stood at about 48 ft BGS across the site. Based on this observation, an attempt was made to collect soil samples no deeper than 48 ft.

4.4.2 Ground Water Analytical Results

A total of twenty-one ground water samples were collected. Four of the wells contained product and ground water samples were not collected in those wells.

All samples were extracted and analyzed within the required holding times. One travel blank, prepared from commercially available distilled water was included with each cooler containing ground water samples. A total of three travel blanks were shipped. One of the blanks was not analyzed since volatiles were not detected in the ground water samples. No analytes were detected in the remaining two travel blanks.

Two blind duplicate ground water samples were submitted along with the other samples for quality control. Sample MWII-39 was a duplicate of MWII-20, and MWII-40 was a duplicate of MWII-30. In both of the duplicates trace concentrations of some constituents were reported, although the original sample was reported as no-detect for all analytes, suggesting that the analytes may be present in these wells at concentrations near the detection limit. However, the differences between the method detection limit and the concentrations reported in the duplicates are not significant for purposes of evaluation of the results.

Split samples were collected for Chevron and Shell Oil Co. representatives, and for the CVRWQCB. The Chevron and Shell Oil Co. representatives requested samples from specific wells. A split sample was prepared from every well sampled for the Water Board, however. By mistake, both the Caltrans sample and the Water Board's split sample were delivered to the Water Board for MW-33. Therefore, MW-33 was resampled on May 20, 1993. The water level was remeasured at that time also.

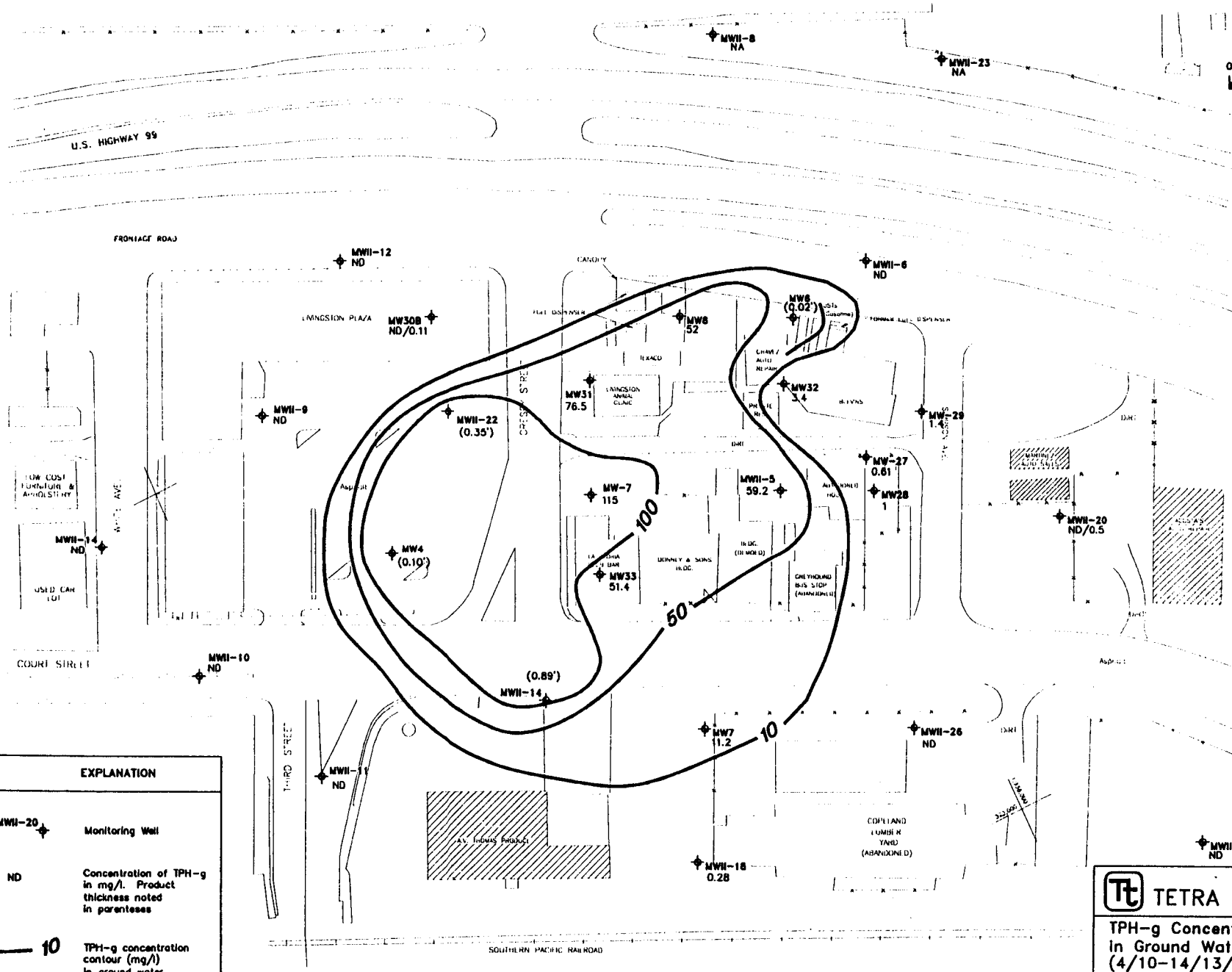
The results of the ground water analyses are summarized in Table 4. Copies of the laboratory reports are presented in Appendix A2. The samples were analyzed for TPH-D, TPH-G, BTEX, and total lead. No lead was detected in any of the samples, at a detection limit of 0.1 mg/L. The TPH-G concentration ranged from 115 mg/L to non-detect. The highest concentration was detected in MWII-7. Gasoline is a mixture of constituents with varying solubilities, most of which are less soluble than benzene. These concentrations in the samples do not appear to be near saturation.

Figure 18 shows the estimated 10, 50, and 100 mg/L TPH-G concentration contours in ground water. The results suggest that the bulk of the gasoline is concentrated west of Cressey Street. No gasoline, diesel, or BTEX was detected in MW-30B, located on the former Chevron site.

TABLE 4 GROUND WATER SAMPLE RESULTS FROM LIVINGSTON FREEWAY (4/10/93 - 4/13/93)

Sample ID	Lab ID	Date Sampled	Date Analyzed	Method 8015 TPH-G (Mg/L)	Method 8015 TPH-D (Mg/L)	Method 8020 Benzene (ug/L)	Method 8020 Toluene (ug/L)	Method 8020 Ethylben (ug/L)	Method 8020 p-,m-Xylenes (ug/L)	Method 8020 o-Xylene (ug/L)	Method 239.1 Tot. Lead (mg/L)
MW-7	4-09885	4/12/93	4/19-27/93	11.2	19.8	1160	37	ND	221	170	ND
MW-8	4-09894	4/13/93	4/19-27/93	52	200	1080	728	ND	1140	838	ND
MWII-5	4-09889	4/13/93	4/19-27/93	59.2	265	2170	830	ND	1430	1090	ND
MWII-6	4-09897	4/12/93	4/19-27/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-7	4-09886	4/12/93	4/19-27/93	115	497	293	1000	2050	820	1950	ND
MWII-9	4-09878	4/9/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-10	4-09877	4/9/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-11	4-09881	4/9/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-12	4-09875	4/9/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	NA
MWII-14	4-09879	4/9/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	NA
MWII-18	4-09876	4/10/93	4/18-20/93	0.28	ND	ND	ND	ND	ND	ND	NA
MWII-19	4-09880	4/10/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	NA
MWII-20	4-09892	4/10/93	4/19-27/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-39 (1)	4-09890	4/10/93	4/19-27/93	0.5	3.2	1	5	ND	13	6	ND
MWII-26	4-09874	4/10/93	4/18-20/93	ND	ND	ND	ND	ND	ND	ND	NA
MWII-27	4-09891	4/10/93	4/19-27/93	0.61	0.88	7	4	ND	1	ND	ND
MWII-28	4-09887	4/12/93	4/19-27/93	1	5.8	3	13	4	31	19	ND
MWII-29	4-09896	4/10/93	4/19-27/93	1.4	8.9	ND	ND	ND	1	1	ND
MWII-30	4-09898	4/12/93	4/19-27/93	ND	ND	ND	ND	ND	ND	ND	ND
MWII-40 (2)	4-09888	4/12/93	4/19-27/93	0.11	0.87	ND	1	ND	ND	ND	ND
MWII-31	4-09899	4/12/93	4/19-27/93	76.5	348	2230	800	ND	1600	1400	ND
MWII-32	4-09895	4/13/93	4/19-27/93	3.4	13.9	52	38	ND	196	181	ND
MWII-33	5-10234	5/20/93	5/27/93	51.4	437	3170	1230	ND	2210	1610	ND
TB-1 (3)		4/9/93		NA	NA	NA	NA	NA	NA	NA	NA
TB-4 (4)	4-09893	4/9/93	4/19-27/93	ND	ND	ND	ND	ND	ND	ND	ND
Trip Blank (5)	5-10235	5/20/93	5/27/93	ND	NA	ND	ND	ND	ND	ND	NA

Notes: (1) MWII-39 is a duplicate of MWII-20.
(2) MWII-40 is a duplicate of MWII-30.
(3) TB-1 sent with samples with lab IDs 4-09874 through 4-09881
(4) TB-4 sent with samples with lab IDs 4-09885 through 4-09899
(5) Trip Blank sent with samples with lab ID 5-10234

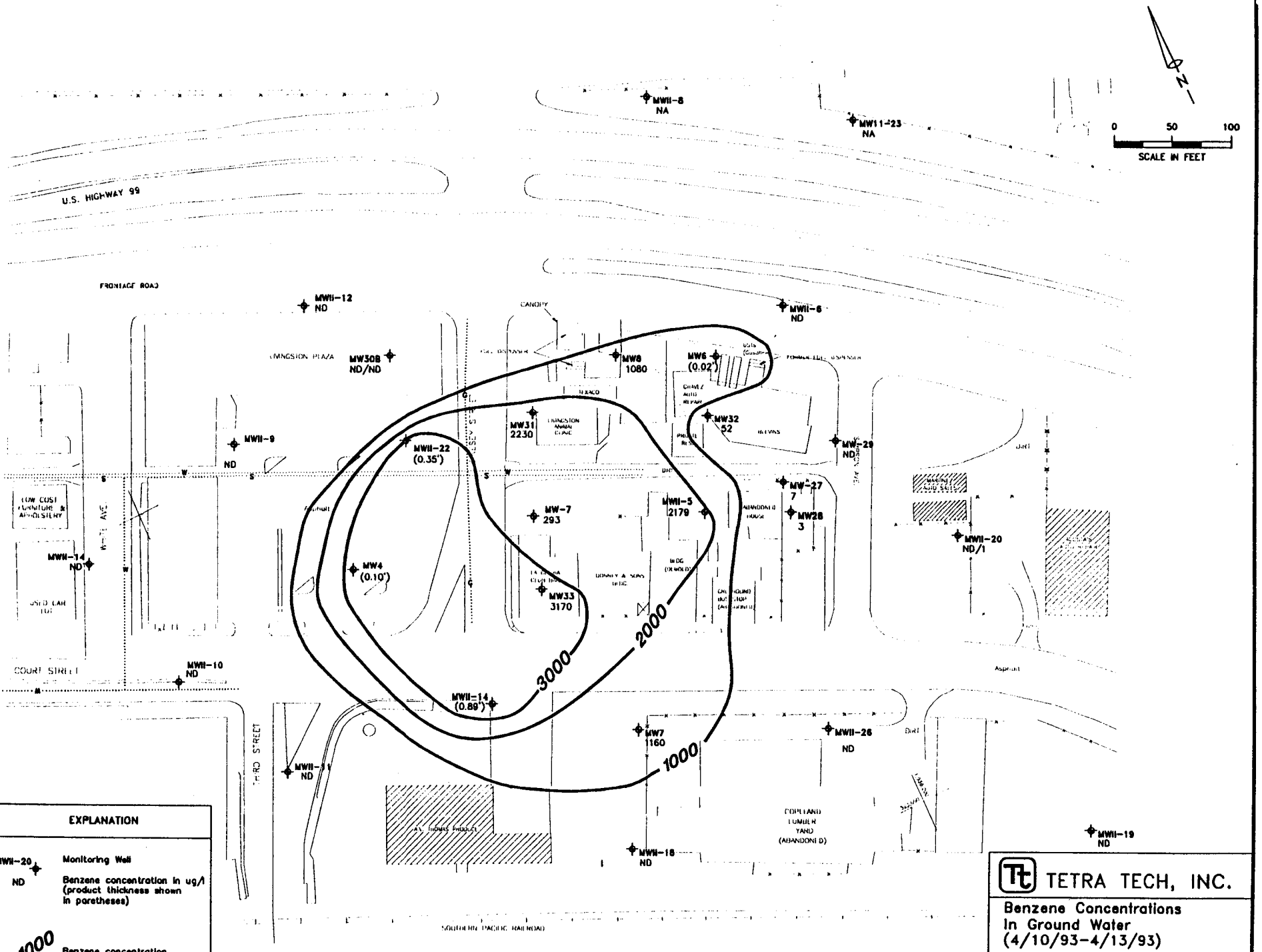


EXPLANATION	
MWII-20	Monitoring Well
ND	Concentration of TPH-g in mg/l. Product thickness noted in parenteses
10	TPH-g concentration contour (mg/l) in ground water

TETRA TECH, INC.

TPH-g Concentrations in Ground Water (4/10-14/13/93)
Site Investigation Report
Livingston, California

Figure 18



TETRA TECH, INC.

Benzene Concentrations In Ground Water (4/10/93-4/13/93)
Site Investigation Report
Livingston, California

Figure 19

Figure 19 shows the concentration contours for benzene. The distribution of benzene generally mirrors that of TPH-G. However, it is apparent from Table 4 that the ratio of benzene to TPH-G in the samples is not constant. The ratio of benzene to TPH-g ranged from 10 percent in MWII-7 to .2 percent in the duplicate from MWII-20. Benzene ranged from not detected to 3,170 ug/L (MW-33). The solubility of benzene in water is about 1,700 mg/L. The sample from MW-33 represents about 0.2 percent of the aqueous solubility of benzene. Comparison of Figures 18 and 19 suggest that the ratio of benzene to TPH-g increases as the concentration of each increases, with the ratio in the range of 3 percent or more in the vicinity of the product plume.

Diesel was reported in most of the ground water samples that contained TPH-G. However, closer inspection of the chromatogram from these samples suggests that the gasoline mixture simply overlaps the diesel range. As was the case for soil samples, the chromatogram for water samples were indicative of gasoline (see Appendix C2 for a brief discussion).

4.5 PRODUCT AND SOIL SAMPLE FORENSIC GEOCHEMICAL ANALYSIS

Selected soil samples were analyzed by EPA Method 8240, in an attempt to identify comparable chemical characteristics of the product in soils and the product floating on the water table. Only four of the soil samples contained significant concentrations of gasoline. The soil sample results are presented in Table 5. Table 5 and Table 6 list all of the compounds identified or tentatively identified in soil and floating product, respectively. Each table contains the full list of the compounds identified in both soil and floating product. Thus, it can be seen in Table 5 that 40 compounds were detected in the soil samples, of which 19 were also detected in floating product samples. Thirty-six compounds were reported in the floating product samples shown in Table 6.

An attempt was made to analyze one soil sample from both high and low in the soil column in each of the borings thought to be near a hydrocarbon release location. Samples in which FID readings exceeded 10,000 ppm were considered candidates for extended analysis. In boring BT7, for example, samples were analyzed from both 33 ft and from 46 ft. In boring BT5, samples were submitted from both 23 ft and from 46.5 ft. BT5-23D contained 2,600 mg/kg of TPH-G. However, the sample from 46.5 ft in BT5 did not contain significant concentrations of hydrocarbons, perhaps because it was too near the

TABLE 5 SOIL SAMPLES RESULTS, GEOFORENSIC ANALYSIS (UG/KG)

METHOD NO.		COMPOUND DETECTED	TETRA TECH/LAB SAMPLE I.D./DEPTH (FT)											
	(1)		BT7-33D 110556-2 33	BT7-46D 110556-3 46	BT8-42D 110556-4 42	BT5-23D 110556-10 23	BT3-48D 110556-1 48	BT8-47D 110556-5 47	BT4-48.5D 110556-6 48.5	BT6-39D 110556-7 39	BT6-46D 110556-8 46	BT5-46.5D 110556-9 46.5	BT2-47D 110519-2 47	MW32-47D 110519-3 32
LUFT		TVH-Gasoline (MG/KG)	310	480	410	2,600	ND	ND	6	7	2	ND	ND	ND
EPA 8240	*	Benzene				3,000	NA	NA	NA	NA	NA	NA	ND	
	*	Toluene	900	1,800	400	120,000								6
	*	Ethylbenzene	3,400	6,100	3,600	5,800								
	*	Total Xylenes	22,000	38,000	21,000	340,000								8
		2-Butanone			300									
	*	Isopropylbenzene												
	*	Propylbenzene	3,100	5,200	4,600	22,000								
	*	1,3,5-Trimethylbenzene	16,000	8,800	7,000	44,000								
	*	1,2,4-Trimethylbenzene	15,000	28,000	17,000	160,000								
	*	sec-Butylbenzene												
		n-Butylbenzene	3,300		4,200									
	*	Napthalene	1,800	3,100	1,500	28,000								
		Acetone												20

TABLE 5 (Continued)
SOIL SAMPLES RESULTS, GEOFORENSIC ANALYSIS (UG/KG)

METHOD NO. (1)	COMPOUND DETECTED	BT7-33D 110556-2 33	BT7-46D 110556-3 46	BT8-42D 110556-4 42	BT5-23D 110556-10 23
	Tentatively Identified Compounds:				
*	Isocyanatomethane				
*	Methylcyclopentane				
*	Tetrahydro-2-(2-propynyloxy)				
*	2-methylpentane				
	2,4-Dimethylheptane	7,500		9,500	
	3,5-Dimethylheptane			7,000	
*	2-Pyrrolidinone				
*	2,3,3-Trimethylpentane				
*	2,2,4-Trimethylpentane			6,000	
*	2,3,4-Trimethylpentane				31,000
	2,3,4-Trimethylpentane				37,000
*	2,2,3,4-Tetramethylpentane				
	2,4-Dimethylhexane		7,000		
	5,7-Demethylundecane		12,000		
*	3-Methylhexane				83,000
*	Octane				
*	3-Methyloctane	4,500			
*	2,7-Dimethyloctane				
*	2,3,4-Trimethylhexane				25,000
*	2,2,6-Trimethyloctane				
	2,4,6-Trimethyloctane			6,000	
	5-Methyl-2-decene		7,600		
*	2,6-Dimethylheptane				
*	2,3,5-Trimethylheptane				
*	4,5-Dimethylnonane				
*	Nonane	4,200	6,600		
	Ethylenediamine, N-(m-	6,000			
*	1-Ethyl-2-methylbenzene	4,500	24,000		150,000
*	1-Ethyl-2-methylbenzene		7,500		58,000
*	1-Ethyl-2-methylbenzene				
	1-Ethyl-3-methylbenzene			16,000	43,000
*	1-Ethyl-4-methylbenzene				
*	(1-Methylethyl)-benzene			6,500	
	1,2,3-Trimethylbenzene		5,900		
*	1-Methyl-3-propylbenzene	5,500	7,800		38,000
	1-Methyl-4-propylbenzene			8,500	
	2,3-Dihydro-1H-idene	4,000			
*	1-Methyl-3-(1-methylethyl)	3,400	12,000	4,000	57,000
	1-Methyl-3-(1-methylethyl)	4,100		6,000	30,000
	1-Methyl-3-(1-methylethyl)				27,000
	2,3-dihydro-4-methyl-1H-idene	4,300	6,000	4,700	
	2,3-dihydro-4-methyl-1H-idene	4,100	5,600		
	1,2,3,4-Tetramethylbenzene		6,600		
	1,2,3,4-Tetrahydronaphth	3,300			
	1,2,4,5-Tetramethylbenzene			5,500	
	1-Ethyl-3,5-dimethylbenzene			7,000	

Notes: (1) Asterisk indicates compounds detected in floating product.

TABLE 6 FLOATING PRODUCT SAMPLE RESULTS, GEOFORENSIC ANALYSIS (UG/L)
(Samples Collected 4/8/93)

METHOD NO.	(1)	COMPOUND DETECTED	TETRA TECH SAMPLE I.D./LAB SAMPLE I.D. MW4-P 110602-1	MW6-P 110602-2	MW22-P 110602-3	MW24-P 110602-4
EPA 8240	*	Benzene	2,000	(700)	6,000	9,000
	*	Toluene	20,000	7,000	57,000	69,000
	*	Ethylbenzene	6,000	8,000	15,000	19,000
	*	Total Xylenes	31,000	41,000	97,000	110,000
	*	2-Butanone				
		Isopropylbenzene		2,000		1,500
	*	Propylbenzene	2,000	7,000	5,000	6,000
	*	1,3,5-Trimethylbenzene	3,000	11,000	11,000	10,000
	*	1,2,4-Trimethylbenzene	11,000	35,000	40,000	40,000
		sec-Butylbenzene		950		
	*	n-Butylbenzene				
	*	Napthalene	1,000	1,000	4,000	5,000
	*	Acetone				
		Tentatively Identified:				
		Isocyanatomethane	17,000			
		Methylcyclopentane				8,000
		Tetrahydro-2-(2-propynyloxy)				8,000
		2-methylpentane				8,500
	*	2,4-Dimethylheptane			8,000	
	*	3,5-Dimethylheptane				
		2-Pyrrolidinone			8,000	
		2,3,3-Trimethylpentane			50,000	
	*	2,2,4-Trimethylpentane		17,000	55,000	
	*	2,3,4-Trimethylpentane	9,800	14,000	32,000	31,000
	*	2,3,4-Trimethylpentane				
		2,2,3,4-Tetramethylpentane	2,400			
	*	2,4-Dimethylhexane				
	*	5,7-Demethylundecane				
	*	3-Methylhexane	16,000			49,000
		Octane	2,600	12,000	7,500	
	*	3-Methyloctane		11,000		
		2,7-Dimethyloctane		26,000		
	*	2,3,4-Trimethylhexane	3,200			
		2,2,6-Trimethyloctane	2,600			
	*	2,4,6-Trimethyloctane				
	*	5-Methyl-2-decene				
		2,6-Dimethylheptane		20,000		
		2,3,5-Trimethylheptane		10,000		
		4,5-Dimethylnonane				10,000
	*	Nonane		9,000		
	*	Ethylenediamine, N-(m-				
	*	1-Ethyl-2-methylbenzene	12,000	20,000	37,000	40,000
	*	1-Ethyl-2-methylbenzene	4,800	6,800	9,000	14,000
		1-Ethyl-2-methylbenzene	2,800			
	*	1-Ethyl-3-methylbenzene				
		1-Ethyl-4-methylbenzene				9,500
	*	(1-Methylethyl)-benzene		7,600	12,000	
	*	1,2,3-Trimethylbenzene				
	*	1-Methyl-3-propylbenzene	3,000	9,200	9,000	9,000
	*	1-Methyl-4-propylbenzene				
	*	2,3-Dihydro-1H-idene				
	*	1-Methyl-3-(1-methylethyl)			14,000	
	*	1-Methyl-3-(1-methylethyl)				
	*	1-Methyl-3-(1-methylethyl)				
	*	2,3-dihydro-4-methyl-1H-idene				
	*	2,3-dihydro-4-methyl-1H-idene				
	*	1,2,3,4-Tetramethylbenzene				
	*	1,2,3,4-Tetrahydronaphth				
	*	1,2,4,5-Tetramethylbenzene				
	*	1-Ethyl-3,5-dimethylbenzene				

Notes: (1) Asterisk indicates compounds detected in soil samples.

water table. Two deep samples were submitted from BT8 at 42 ft, and at 47 ft, but no shallow sample was submitted. The small statistical sample represented makes comparison of the soil samples with floating product samples unproductive.

Product samples were collected in four of the monitoring wells in the network. The product was of varying thickness. Product thickness measurements are shown in Table 2, and on Figures 14, 15, 18, and 19. Historical product thickness measurements are presented in Table 2 and on Figures 3 through 9.

Floating product samples were shipped to Curtis & Tompkins Laboratories, Ltd, in Berkeley, for analysis by EPA Method 8240 and detailed interpretation and evaluation of the chromatogram. The results are summarized in Table 6.

7 EVALUATION AND DISCUSSION

5.0 DATA EVALUATION AND DISCUSSION

This section discusses the significance of the results described above.

5.1 HYDROGEOLOGY

Geological structure and stratigraphic features can be important influences on contaminant migration. This investigation focused on identifying such features in the vadose zone. The results indicate that a continuous hard pan layer is present in the interval 15-20 ft. Below this lay there are no stratigraphic features likely to impede the migration of gasoline to the water table. Subsurface materials are highly permeable to gasoline, and there are relatively few fine-grained beds that would absorb gasoline or cause it to migrate horizontally. Ubiquitous elevated FID readings in vadose zone samples collected far from the presumed potential source areas along Frontage Road (for example in the boring of MW-33), indicate that potentially large amounts of gasoline floating product have volatilized into the vadose zone. The vapor appears to be largely trapped below the hard pan and silt horizon that occurs between 15 to 20 ft BGS.

Evaluation of historic water level data from previous investigations of the site, and of the data collected in this investigation, suggest that the hydraulic gradient beneath the site has evolved during the past 5 or more years from a westward to a southward direction. Factors which may have influenced this change include lowering water levels, and local influence from nearby pumping wells. One well, which may have influenced the site in the past, is the City of Livingston's well, located south of the site, near the Police Station. This well has recently been shut down due to contamination by DBCP. However, if the well is screened across an aquitard separating the contaminated upper aquifer from the deeper production zone, the well still may act as a drain to the deeper zone. Alternatively, there may be other wells south of the site which account for the depression observed south of MWH-19.

As water levels have declined, they have gradually dropped below the base level of the Merced River and the canals and aqueducts serving the area. In the past, ground water would have discharged to the Merced River. However, at the present time the water table is below the level of the river, and water tends to flow from it to the aquifer. This change would cause the gradient to rotate southward, or toward any large regional pumping center.

At the site scale, the evidence from water levels since 1989 suggests that ground water flows in a wide arc southward beneath Cressey Street, and then southeast toward MWII-18 and MWII-19. An anomalous ground water mound beneath the region of the former Livingston Animal Clinic is indicated by water levels in MWII-7, which have recently been supported by the water level measured in MW-31. The origin of the mound is not known. No evidence of shallow saturated soils was observed during drilling of MW-31, to suggest that there may be a source of recharge in this area, such as from a leak in the water or sewer mains that run under the former alley. The higher water levels could result from delayed drainage from less permeable sediments during rapidly decreasing water levels, but this seems unlikely.

5.2 GASOLINE DISTRIBUTION IN SOILS

The distribution of gasoline in soils, from this investigation and previous investigations, suggests that the most significant spill areas are located in the vicinity of former tanks, fuel dispensers, and associated piping on both the property at 1410 Highway 99 and the property at 1444 Highway 99. Gasoline is present over the entire soil column at several locations in these areas, indicating that these locations were near to a spill. No evidence of a spill was found in the shallow soils on the property at 1344 Highway 99.

The water table has decreased from a depth of about 20 ft below the surface prior to 1960 to a depth of more than 50 ft below the surface today. A hardpan layer was identified in the interval between 16 to 20 ft below the surface. A regional perched aquifer has reportedly been associated with this hardpan in the past. The hardpan marks the top of the Riverbank formation.

The hardpan apparently now acts as a low-permeability barrier to upward vertical migration of gasoline vapor. Gasoline vapor was not observed in soils shallower than the hardpan except near

presumed source locations. Below the hardpan and to approximately the present depth of the water table, soils consist of a relatively homogeneous, loose, friable, permeable gray silty sand. This interval does not appear to contain any significant fine layers that might impede the downward movement of gasoline or retain the gasoline. The hardpan layer, and the micaceous interbeds overlying the hardpan, is the sort of stratigraphic zone that should retain gasoline and cause it to migrate laterally at a spill site. The hardpan is not well-cemented, and was not impenetrable to vertical migration of gasoline.

Gradually, during this period of decreasing water levels, the direction of ground water flow has shifted from westward to southward, as the gaining reach of the Merced River has moved downstream. The elevation of the Merced River is about 85 ft at the Highway 99 bridge, about one mile northwest of the site. The river at this point is about 5 ft higher than the present elevation of the water table at the site. When the gasoline from the leaking tanks and pipelines encountered the water table, and if the leak was rapid, the gasoline would have pooled and begun flowing radially, but more rapidly in the direction of the slope of the water table. The conductivity of a given permeable material is less for gasoline than the hydraulic conductivity, due to the lower viscosity of the gasoline. This means that the gasoline could have flowed faster than ground water under equal gradients. The gradient of gasoline would have been larger than that of the water table close to the source, though, since the gasoline was thickest there.

In 1989, when the water table was 10 ft higher than it was in 1993, product was reported to be 1.66 ft thick in MW-4. Only 470 mg/kg of gasoline was detected in the soil sample collected from 35 ft in the boring of MW-4. By contrast, in MWII-22, which is upgradient of MW-4 and was drilled one year later, the concentration in the soil sample collected at 35 ft was 10,000 mg/kg, and it was 87,000 mg/kg in the sample from just above the water table at 40 ft. These results suggest that the gasoline product did not migrate upward into the vadose zone from the water table to any significant extent, but was instead retained on the soil after the water table dropped. If this is true, then the product plume probably had no yet reached MW-4, but had reached MWII-22 when the water table was at 35 ft. Depending on how long the residual gasoline is retained on the soil after the water table drops, a map of the depth above which gasoline concentrations on soil decrease dramatically should provide an indication of the depth of the water table when the product plume originated.

The source areas of the gasoline are generally located within a strip about 25 ft wide along Frontage Road, within the 1410 and 1444 Highway 99 properties. The boring locations at which gasoline

is high in the vadose zone include MW-8, BT-5, BT-7, and BT-8. No potential source of gasoline is known to be present north of Frontage Road. Soil concentrations that are likely associated with residual floating product left behind by a decreasing water table (rather than lateral migration through the vadose zone) are found at a depth of 31 to 33 ft in BS-5 and at a depth of 34 to 39 ft in BS-8. BS-8 is about 65 ft north of MW-8, and upgradient. The floating product layer probably sloped radially away from the source, and the thickness of the floating product was probably not great at BS-8, while it would have been thicker at BS-5, which is only 40 ft from MW-8. The same sharp increase in gasoline concentration occurs in BS-7 at a depth of between 29 to 34 ft. BS-7 is about the same distance from MW-8 as is BS-8. These data suggest that the water table was at a depth of between 29 to 34 ft when the product plume first formed beneath a source area close to MW-8 or BT-5.

Since the depth of the break in concentration in MWII-22 occurs at 35 ft, the product plume apparently spread rapidly toward the west. Our results suggest that the plume was narrow or the residual gasoline at the depth of the former water table has dispersed fairly rapidly in the three years since CKY performed their investigation of the site. We found very low concentrations in soils at BT-2, BT-3 and MW-31 all the way to the depth of the water table, while concentrations in BL-2 in the 30 to 35 ft depth range, and in BL-3 in the 35 to 40 ft depth range showed elevated gasoline concentrations. If the gasoline has dispersed from the 35 ft zone during the last three years, then the 29 to 34 ft depth assumed for the water table at the time the product plume was initiated is probably a lower limit. The leak(s) that created the product plume may have occurred earlier, when the water table was higher than 34 ft. Caltrans data suggest that the water table fluctuated in this range during the period between 1969 to 1987. Simple extrapolation of the water table decrease during the past three years suggests that the water table was last at a depth of 29 to 34 ft prior to 1985 or 1986.

A soil cleanup level of 50 mg/kg has been set for the site. Soils in the source area are characterized be high concentrations which are probably confined to a relatively small vertically cylindrical regions near the leak. The existing data are not adequate to precisely define the extent of these regions. However, assuming that a cylindrical region with a radius of 15 ft contains all of the contamination greater than 50 ppm at each of the four potential source locations identified to date (BT-5, MW-8, BT-7, and BT-8), the combined volume contained in these regions between a depth of 10 ft and 45 ft (the highly contaminated region above the water table) is approximately 3700 cu yds. Assuming that the average concentration of gasoline in each of these cylindrical regions is the average of the soil sample

concentrations reported for the borings at these locations (average concentration = 2,600 mg/kg), and further assuming that the soil density averages 1360 kg (1.5 tons) per cu yd, the contaminated soil contains about 13,000 kg of gasoline. Assuming that the specific gravity of gasoline is 0.75, there are 2.72 kg of gasoline per gallon, and the 13,000 kg of gasoline represents 4,800 gals of gasoline.

Additionally, there appears to be a region above the water table (between 35 ft to 50 ft) in which residual floating product has been retained on the soil as the level of the water table has dropped. The impacted region includes the region through which the floating product plume migrated, which roughly corresponds with the area shown in Figure 17, between 35 ft and the water table. The concentration of residual gasoline in this region is difficult to determine because the concentrations may have changed since samples were collected in 1989 and 1990. The area of the impacted region is approximately 45,000 sq ft, and the volume of soil contained within the region is therefore, approximately 675,000 cu ft (25,000 cu yds). If it is assumed that the average residual concentration of gasoline in this region is 2,600 mg/kg, the total mass of gasoline (using the same assumptions as above) is 88,000 kg. This is equivalent to approximately 32,500 gals of gasoline.

By comparison, the amount of gasoline present as vapor in the soil porosity above the water table is small. Gasoline vapor has been observed in the vadose zone between 20 ft and 50 ft over a wide area. Assuming that the affected region has an area of 100,000 sq ft, is 30 ft thick, and has an average vapor filled porosity of 35 percent, the total volume of the pore space is 1.05 million cu ft. If the molecular weight of gasoline is assumed to be 100 g/mole, and the concentration of the gasoline vapor is assumed to average 3,000 ppm, then the volume of gasoline represented by soil vapor, converted to its liquid equivalent, is only about 80 gals.

5.3 GASOLINE DISTRIBUTION IN GROUND WATER

The gasoline distribution in ground water supports the hypothesis that the former underground fuel tank systems at 1410 and 1444 Highway 99 are the principal sources of ground water contamination. The highest ground water concentrations are associated with the principal product plume west of Cressey Street, although a separate smaller plume exists close to MW-6, and may formerly have been linked to product found in MWII-5. The area impacted by TPH-g concentrations greater than 10 mg/L correlates

well with the region containing benzene concentrations greater than 1000 ug/L. This region covers an area roughly 300 ft by 400 ft, or about 3 acres. The vertical extent of the region is not known. Ground water samples represent the vertically averaged concentration to the depth of the well, but most of the wells currently extend only one to two ft below the water table. The concentration near the water table probably represents the maximum concentration that occurs, since it is associated with floating product and residual contamination in the capillary zone. Assuming that the area of the dissolved ground water plume is approximately 100,000 square ft, and that the concentration of gasoline decreases with depth so that the contaminated zone is 50 ft thick, and the saturated porosity is approximately 35 percent, the volume of water within this zone is 1,750,000 cu ft. The average concentration in the shallow ground water can be estimated from the concentrations shown on Figure 18, based on an assumption that one third of the 100,000 sq ft surface area is within the 100 mg/L contour and averages 250 mg/L, one third is between the 50 and 100 mg/L contour and averages 75 mg/L, and the remaining one third averages 25 mg/L. The weighted average concentration in the shallow surface zone is then 115 mg/L. If the average concentration of gasoline in the zone to a depth of 50 ft is taken to be one-fourth of this weighted average concentration (29 mg/L), then using the conversion factor of 28.3 liters per cu ft results in an estimated mass of gasoline dissolved in the ground water of 1,436 kg. This is equivalent to approximately 530 gals of gasoline.

There are no data regarding vertical hydraulic gradients at the site, although it is probable that there is a vertical downward gradient due to local and regional pumping of deeper units for irrigation and drinking water.

5.4 GASOLINE PRODUCT DISTRIBUTION

The floating product appears to be present in two distinct plumes. One plume is peanut-shaped and presently covers an area that includes MWII-22, MW-4, and MWII-24 as shown in Figure 15. This area is roughly 100 ft wide and 300 ft long. The average thickness of the product in this region is estimated to be one half to one-fourth the average thickness of the product in the three wells, or about 0.1 to 0.2 ft thick, based on the assumption that the product thickness observed in a well is typically greater than the thickness outside the well. Using a conversion factor of 7.48 gals per cu ft, and assuming

that the volume of the gasoline plume is 100 ft x 300 ft x 0.1 ft, the total volume of gasoline in this plume is 22,440 gals.

A second, much smaller plume apparently has its source near MW-6. The thickness of this product plume may average 0.01 ft over an estimated area of less than 1000 square ft, representing a total volume of less than 75 gals.

The sum of the estimated quantities of gasoline in floating product (22,440 gals), in soil associated with spill sites (4,800 gals), and in the vapor phase (80 gals), is approximately 27,320 gals. This amount of gasoline could be produced by a leak of about 37 gals per day over a period of two years. If the estimated 32,500 gals of residual gasoline contained in the vadose zone and the estimated 530 gals of dissolved gasoline in ground water are added, the total volume would be approximately 60,000 gals. This is equivalent to a loss of 82 gals per day over a period of two years.

5.5 GASOLINE PRODUCT CHEMICAL CHARACTERIZATION

A brief report based on the interpretation of the gasoline product sample results was prepared by Dr. Bruce Godfrey, Ph.D., an expert on the chemical analysis of hydrocarbons at Curtis and Tomkins Laboratories, Ltd, in Berkeley, California. The report is presented in Appendix D, and summarized here. Based on the laboratory's analysis of the four product samples collected by Tetra Tech on April 8, 1993, and submitted to the laboratory on April 9, 1993, Dr. Godfrey concluded that:

(1) All product samples represented weathered gasoline with approximately 50 percent evaporation of benzene; and

(2) The product collected from MW-6 represents a different composition from the other three samples (from MW-4, MWII-24, and MWII-22), which are closely similar in composition.

The age of the product was not determined in the present study. However, the estimated reduction in benzene concentration obtained by Curtis and Tomkins was greater than that reported by Chevron.

The conclusion that the product from MW-6 is distinct conforms with the conclusion previously reached by Chevron.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 VOLUME AND EXTENT OF CONTAMINATION

The total volume of gasoline present in soils at the source locations and in floating product is about 27,000 gals. An additional unknown volume of residual product may be present throughout the region between about 35 ft and 50 ft, the zone above the water table through which the floating product plume has migrated. This represents gasoline that was trapped in the sediments as the level of the water table has dropped during the past 5 or more years. This volume is estimated, with a high degree of uncertainty, to be as much as 32,500 gals. An unknown volume of gasoline, tentatively estimated to be 530 gals, is also present in the dissolved phase in ground water. A relatively insignificant volume of gasoline (estimated to be 80 gals) is present in the vapor phase in the vadose zone.

6.2 GEOCHEMICAL INTERPRETATION

The contamination present on the site is weathered gasoline, containing an estimated 50 percent of the original benzene concentration. The lost benzene may have undergone biodegradation, evaporated, and/or preferentially dissolved in soil moisture or ground water (due to the higher water solubility of benzene relative to most other hydrocarbons in gasoline). The age of the gasoline is not known, but it may be older than previously estimated by Chevron, since the benzene to gasoline ratio determined in this study was greater than that determined by Chevron. The geochemical data suggest that there were at least two distinct sources of the product in ground water.

6.3 POTENTIAL SOURCES OF CONTAMINATION

Our interpretation of the historical and current data leads us to the conclusion that there are two distinct product plumes at the site. One plume originated in the vicinity of MW-6, and is probably the

result of a leak or leaks from the former underground storage tanks, dispensers, and piping previously located at 1444 Highway 99. Evidence from soil borings suggests that there were at least two leaks in this area of the site that could have impacted ground water, including one near an 8,000-gal gasoline and a 5,000-gal gasoline tank, and another located at the former fuel dispenser associated with these tanks. Soil sample results from borings BT7 and BT8, which were located near the former tanks and the dispenser island, respectively, support this conclusion.

The principal floating product plume appears to have had its source(s) on 1410 Highway 99, in the vicinity of MW-8 and BT-5. The product plume that originated from this leak is presently disconnected from the source area. The floating product moved as a slug in the direction of ground water flow. The center of mass of this slug has migrated to a position estimated to be located between MW-4 and MWII-24. The path of the center of mass of this slug described an arc that moved westward at first, under the influence of a westward hydraulic gradient, and then turned southward in recent years as the hydraulic gradient rotated southward.

This leak may be associated with the former pipeline from tanks on 1444 Highway 99 to the dispensers at 1410 Highway 99, or with a leak in tanks that were removed prior to the time the pipeline was built, or with a leak that occurred at the south dispenser island itself (near BT-5).

A leak in the pipeline was reportedly discovered in 1986 and repaired (G. Sweeten, personal communication). This time period for discontinuation of the source is consistent with soil data that suggest that the depth to ground water at the time of the leak was about 29 to 34 ft. If the leak had not been repaired prior to 1990 when an extensive ground water monitoring network was installed, then the product plume would not have been observed to be disconnected from the source area. The hydrologic evidence also suggests that the disconnection of the plume must have occurred prior to 1989, since by 1989 the hydraulic gradient had already shifted to the southwest.

Alternatively, or in addition to the pipeline leak, there may have been a significant leak in one or more of the gasoline tanks that were removed when the pipeline was installed. The date of this event is thought to have been between 1981 to 1986. The tanks might have been removed and the pipeline from 1444 to 1410 Highway 99 installed in response to the discovery of a leak in the tanks.

6.4 FUTURE ISSUES

If the level of the water table continues to decline many of the existing wells in the monitoring well network will become dry. Determining the direction of the hydraulic gradient coming on to the site will be difficult without MWII-8 and MWII-23, which are located north of Highway 99. The elevations of the bottom of the screens on the monitoring wells are included in Table 1.

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